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Observations of the California Countercurrent

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THESIS

OBSERVATIONS OF THE
CALIFORNIA COUNTERCURRENT

by

Robert L. Harrod

June 1984

Thesis Advisors: J. B. Wickham
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California Countercurrent

by

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I. INTRODUCTION AND BACKGROUND

Eastern boundary currents are the subject of scientific investigation for a variety of reasons, particularly the impact of these currents on the fishing industry. Ryther (1969) concluded certain fishing grounds such as those off Peru, California, northwest and southwest Africa, Somalia, and the Arabian coast are so fertile, that they supply over half of the worlds fish harvest, yet constitute less than one percent of the oceans. These fishing grounds are invariably located close to shore, and their great fertility is due to frequent replenishment of near-surface nutrients from a few hundred meters deep in the open ocean offshore. The primary process for this is coastal upwelling, which in the Western Hemisphere is associated most markedly with the eastern boundary currents off North and South America. The economic need to understand these currents is made evident by the devastation of the coastal regions of Ecuador and Peru in 1982-1983 by the sudden influx of warm water termed El Niño. The socioeconomic effects included; flooding, landslides, destruction of transportation facilities, huge agricultural losses, disturbance of coastal fisheries, and loss of life (Halpern et al., 1983). This warm water influx takes place from

time-to-time, and recovery from a severe occurrence may take several years (Smith 1983).

Off the North American west coast, the eastern boundary flow regime is known as the California Current System. A comprehensive summary of the present knowledge of this system is given by Hickey (1978). The California Current System includes the southward flowing California Current, and a number of manifestations of a counter-flow: the California Undercurrent, the Davidson Current, and the Southern California Countercurrent. This system is part of the general circulation of the North Pacific Ocean which is dominiated by an oceanwide, clockwise circulation known as the North Pacific Gyre. The eastern limb of the gyre is the California Current System, which extends along the North American continent from southern Canada to Mexico. The system includes both poleward and equatorward flows which vary on many time-scales. There are, for example, inter-annual variations such as El Niño, seasonal variations, and large variations with periods associated with weather systems. The California Current is a slow and broad equatorward surface flow, branching from the North Pacific Current, and marked by cold subarctic water type. The waters of the various countercurrents may be characterized by their admixture with water of equatorial origin which has relatively high levels of temperature, salinity and phosphate, and relatively low dissolved

oxygen. During the winter months a surface current with poleward flow occurs in nearshore regions off the west coast of the United States. This current, inshore of the California Current, is known as the Davidson Current and is ordinarily found north of Point Conception. The Davidson Current may be a surface manifestation of the California Undercurrent. The Southern California Countercurrent is the name applied to the poleward flow from San Diego to Point Conception; during winter months, this nearshore flow is sometimes continuous with the Davidson Current.

The study of eastern boundary currents is of both theoretical and practical interest. Dynamical models with features of observed eastern boundary currents have been developed since the turn of the century. Ekman (1905) described the effects of a steady wind blowing on an ocean, and stated the concepts now known as the Ekman spiral and the Ekman transport. Sverdrup, Johnson, and Fleming (1941) provided some understanding of the dynamics of the upwelling process. Munk (1950) computed the mass transports in a wind-driven ocean from the curl of the estimated wind stress.

Recent models include the two-dimensional and three-dimensional upwelling models, and sea breeze produced upwelling models reviewed by O'Brien (1977). These models considered the influences of horizontal boundaries, bottom topography, and the variability of wind stress on the

ocean. The first numerical model of coastal upwelling was constructed by O'Brien and Hurlburt (1972); this two-layer model successfully predicted the observed equatorward jet but failed to produce a poleward undercurrent. Suginohara (1974) used a model with a straight coast and a bottom topography which did not vary in a coastwise direction. His model succeeded in developing a poleward flow in the lower layer. A later review of models is given by Allen (1980). These models permit inferences, such as the effects of shelf width and coastal winds, to be made about shelf-flow motions which have time scales like those of the atmospheric weather systems which drive them. Irregularities of the coastline and bottom topography force three-dimensional motions. However, there has been little theoretical work in this area until recently. An important conclusion from the models is that the currents arise from and are maintained by both local and remote atmospheric forcing. Significantly improved models of coastal upwelling include more realistic wind stress and finer resolution of bottom topography, especially the shelf break and steep bottom slopes.

Complementing models are field experiments which provide the basis for their motivation and verification. Two recent comparisons of models to field observations are Hickey (1980) and Janowitz (1980). Hickey used the two-dimensional, baroclinic, time-dependent model of

Hamilton (1978) and found it to be effective for time periods as long as fifteen days in predicting the displacement of isopycnals off the Oregon coast. Janowitz's comparison of a model of time-dependent quasi-geostrophic upwelling to moored meter data concluded tentatively that the model may have some validity, but further comparisons and verification should be undertaken.

Early observational studies of the California Current System emphasized relatively large-scale motions. Sverdrup and Fleming (1941) utilized T-S relationships to define the origins of water of two sorts (in northern hemispheric eastern boundary flows): northern water with increasing salinity as temperature decreases with depth and southern water with relatively constant salinity as temperature decreases. That the warmer water was a northward-flowing current was also demonstrated by Sverdrup and Fleming (1941) utilizing geostrophy; later, Reid, et al. (1958) showed that geo-strophic shear of the flow at the 200-dbar surface with respect to the 500 and the 1000-dbar surfaces indicates a northward flowing undercurrent. During the fifties and early sixties most Lagrangian current measurements were limited to drift bottle estimates of surface currents. One important exception was the tracking (for a few days) of deep drogues by Reid (1962), which also indicated a northward-flowing undercurrent off the central California coast. It is in the last decade that moored

current meters have provided a means to examine details of the flow over long time-periods. Moored current meters can be positioned to give direct measurements of the currents over extended periods (approximately two months for the Aanderaa meter, if a ten-minute sampling interval is used). Moored meters provide an excellent means for detailed local studies to elucidate better the properties, relationships, and interactions of the several portions of the California Current System. Studies of the California Current System during the 1960's using moored meters were primarily of the coastal waters off Oregon and Washington. While few current measurements have been made in the California Current and reliable wind stations are sparse, continuing studies off Washington and Oregon by Hickey (1979, 1980) and Huyer et al. (1979) show a significant relationship between local wind forcing and currents. Hickey stated that the seasonal variation of the nearshore region of strong flow appears to be related to the seasonal variation of the alongshore component of wind stress at the coast. Huyer et al. show that the transition from the predominantly northward surface currents of the winter oceanographic regime to the predominantly southward surface currents of the spring oceanographic regime over the Oregon continental shelf occurs within a period of several days during a strong southward wind event. Recent work for waters off the central region of the California

coast includes descriptive studies by Wickham (1975), Coddington (1979) and Dreves (1980). Wickham (1975) made salinity-temperature-depth (STD) sections, and parachute drogue observations off Monterey Bay. Wickham found the California Countercurrent to be present 15 km off the coast in August 1972 and in August 1973. Coddington (1979) compared direct current measurements from an array moored off Cape San Martin to indirect measurements from geostrophy. Coddington found the California Countercurrent to be present during the study period from November 1978 to February 1979. Dreves (1980) studied the relationship between local sea level gradient and alongshore flow for the same study period as Coddington. Dreves found that current and sea level gradient energy distributions were in close agreement, showing high energy concentration at the low frequency end of the spectrum.

The region of the central California coast off Cape San Martin (Figure 1) was chosen for study for several reasons: there is relatively little ship traffic or fishing and, consequently, less risk of current meter damage or loss; the bottom topography is relatively devoid of complications, consisting of an extremely narrow shelf, sharp shelf break, and depth contours approximately parallel to the coast; additionally, the close proximity of the study area to Monterey was a logistical convenience.

The current meter data used by Coddington and Dreves,

some six sets of current meter observations spanning six months from 25 July 1978 until 22 January 1979, have been augmented as part of the continuous monitoring of the countercurrent off Cape San Martin. An observational data base of direct current measurements of more than one year's duration now exists.

The objective of this study is to provide a preliminary analysis of current meter data for the period January 1979 to April 1980.

II. DIRECT CURRENT OBSERVATIONS

A. DATA COLLECTION

The data for this study were collected using Aanderaa Model RCM-4 recording current meters, which are self-recording and intended to be anchored in the ocean below the wind wave zone; they record current speed and direction and water temperature.

The meters were deployed off Cape San Martin, California, from August 1978 until July 1980 (see Figure 2). The station locations are shown in Figure 3. The present study covers the period from January 1979 to May 1980. Coddington (1979) and Dreves (1980) have discussed data collected during the period from April 1978 to January 1979. Deployment of the arrays was accomplished with the Naval Postgraduate School's research vessel ACANIA. Each mooring of several meters was launched by being strung out behind the ship, the uppermost meter and flotation devices first and the anchor last. The array's descent was slowed by a small drogue about two meters in diameter attached to the anchor. An array of three meters was used at Station 2 (35° 52.16'N, 121° 33.76'W) and four meters at Station 7 (35° 51.4'N, 121° 46.54'W). They were arranged approximately as depicted in Figure 4. The anchor consisted of

one or two railroad wheels attached to an AMF-Sealink Model 242 acoustic release. Benthos 17-inch glass spheres in plastic hard hats (55 pounds net buoyancy each) were used to provide wire tension, with two spheres directly above each current meter and six above the release. The entire array was moored below the region of strong surface wave action and was recovered by acoustically activating the release. Upon recovery the meters were returned to the laboratory for maintenance prior to subsequent redeployment.

B. DATA PROCESSING

The data were recorded on three-inch reels of 1/4-inch audio tape (Scotch Brand number 295) at ten-minute sampling intervals. Conversion of the data from the tapes recorded by the RCM-4 meters into a computer-acceptable format was accomplished with a Hewlett-Packard 9845 computer and an Aanderaa tape translator. The 1/4-inch tape was played back on a Wollensach audio deck and an oscilloscope was used to give a visual confirmation that data were present and of appropriate amplitude. The data were then translated from long and short to high and low voltage pulses and recorded on IBM-compatible 9-track tape on a Kennedy 9-track tape recorder. The Hewlett-Packard 9845 computer was also used to plot and print portions of the data.

Five different programs were used with the Naval Postgraduate School's IBM 360 computer in processing the data. They are listed in Appendix D. The initial program reads in the raw data from the 9-track magnetic tape, allows an initial look at the data if desired, and stores the data in mass storage for quicker, more efficient utilization. The second program applies temperature, speed, and direction calibrations to the data for each current meter. The third program reads in the calibrated output from program two, identifies missing records, and uses established cut-off parameters to suppress noise. Temperatures greater than 12°C, and less than 5°C are discarded, along with current speeds in excess of 100 $cm\text{-}s^{-1}$. Discarded and missing records are filled in by the following process: upon encountering a faulty value, searching continues until a value is found that meets the acceptance criteria. Linear interpolation is used to obtain fill-in values. Initial looks at the data revealed only minimal gaps in the records. Program three, by means of a binomial, converts the data record from ten-minute values to hourly values and then produces four plots. Currents are presented in the form of stickplots, and three other plots display U and V components of the current (respectively, eastward and northward for positive values), and temperature as functions of time. The fourth program reads in the output of program two, fills in missing and

faulty records, and then performs a spectrum analysis of the data. Its output consists of two plots of frequency versus power density for onshore and alongshore components of current. The fifth program uses the hourly records produced in program three to construct progressive vector plots. Two of the current meters used in the study were very noisy and gave unrealistically high indications of the speed. These noisy data are not shown here.

III. STUDY OBJECTIVES

The objective of this study is to provide a preliminary analysis of the current meter data. Questions to be considered are:

1. Do the data reveal seasonal variations of the flow?
2. Do the data reveal differences or similarities in the flow between Stations 2 and 7?
3. Are there indications of mesoscale events?
4. Are such mesoscale events coherent with respect to depth and/or position?
5. Is there a generalization about variation with depth that can be made?
6. How do the currents appear to be related to Bakun's coastal upwelling index (Bakun, 1980)?

IV. DESCRIPTION AND ORGANIZATION OF GRAPHICS

To highlight the salient features of the variations, and to examine them in the framework of Section III the data are presented in several ways. There are seven different graphical representations in Appendixes A, B, and C. These plots are:

1. Time series of Bakun's coastal upwelling index (Bakun, 1980).
2. Time series of current vectors.
3. Time series of eastward components of the current vectors.
4. Time series of northward components of the current vectors.
5. Time series of temperature.
6. Spectrum analyses of alongshore flow and on/offshore flow.
7. Progressive vector diagrams.

The plots are organized chronologically according to deployment date of the meters, beginning 5 January 1979 and ending in March 1980.

In Appendix A there are sets of time series. For example, Figure 8 and those like it contain time series of Bakun's coastal upwelling index (UI), and current series

(stickplots), in this case for the meters deployed on 5 January 1979 at Station 7, permitting visual comparison of one aspect of local forcing and the associated motions. The coastal upwelling indices are indicative of onshore-offshore Ekman transport, as estimated from wind stress at the position in the vicinity of Point Sur indicated in Figure 1. The procedure for calculating upwelling indices is presented in detail by Bakun (1973). The stickplots are graphical depictions of current speed and current direction. Time-scales are indicated along the top and bottom of Figure 5, and the units of measurement for the ordinates are shown on the left side of the figure. Pertinent information on the figures of this type include: station number, date of deployment, meter serial number, and depth of meter deployment.

Another type is represented by Figures 6 and 7. They depict U, V, and T for the two current meter records represented in Figure 8, where U (positive) is the eastward component of the current vector, V (positive) is the northward component of the current vector, and T is the temperature. Again, time scales and pertinent station information are given in the figure. The time series of these variables are complementary to the progressive vector diagrams found in Appendix C since they accentuate higher frequency events such as inertial and tidal oscillations.

The figures in Appendix B contain spectrum analyses of

alongshore flow and on/offshore flow for each current meter. The abscissa (frequency) and the ordinate (power density function) are clearly labeled, and each figure also lists station number, meter serial number, meter deployment depth, and date of deployment. The spectrum analyses indicate regions of high energy in the frequency domain and suggest forces at work.

Appendix C contains the progressive vector diagrams (PVD). The vertical and horizontal scales are equal (kilometers), and true North is indicated. Crosses are positioned at 3-day intervals, and the letter "F" indicates the final plotted position. In addition to station number, meter number, meter depth, and period of computation, the mean speed and mean direction for the entire period are indicated. The PVD's depict well the low frequency variations, so-called "events", such as eddies.

Appendix D contains the listings of the computer programs used to process and plot the current meter data.

V. ANALYSIS

A. RELATION BETWEEN CURRENT AND LOCAL WIND FORCING

The coastal mountains of California tend to deflect the low level winds so that they blow equatorward parallel to the coast. Consequently, the average Ekman transport is offshore (Stewart 1967). In the simple Ekman model, the offshore flow lies generally above the level at which our current meters are moored. But there are strong vertical motions (up-and-downwelling) and other intense mesoscale exchange mechanisms in the area of study which negate the application of the simple Ekman model to observed cross-slope flow and suggest the possibility of a deeper "virtual" Ekman layer extending well into the pycnocline.

In this section qualitative relations between current and local wind forcing are examined through use of the time series of stickplots and upwelling index and also by referring to Figure 5. These relations will first be examined separately at each mooring station, and then for the time period July - August 1979, when current meters were deployed at both Station 2 and Station 7. Finally, seasonal and geographical variations will be considered.

1. Analysis at Station 2

The corresponding UI and current velocity for Station 2, the inshore station, are shown in Figure 11 for the period from 23 April to mid-June. There are event-scale (ca. one week) changes in current direction and speed that appear to be coherent with depth. The upwelling index is positive all during the months of May and June with nearly periodic episodes of great intensity. It is reasonable that there be upwelling in this period of strong positive upwelling index ($\overline{UI}$=+138). The mean cross slope flow ($\overline{U}$') for this period (Table II) is small and positive, which indicates that the meters are below the Ekman layer. The poleward alongshore flow shown by the stickplots indicates the presence of a countercurrent at 169 and 241 m. Strong equatorward winds (positive UI) seem to correlate well with strong poleward flow of the countercurrent during this time period, especially at the level nearest the surface. Also, very large drops in the index are associated with a slightly lagging decrease in the poleward current speed, and increased variablility in current direction during intervals centered on 21 May, 1 June, and 9 June (Figure 11).

Continuing at Station 2 in the period 21 July - 12 September 1979 (Figure 18), there is also an overall tendency for poleward flow associated with positive upwelling index especially at the level nearest the surface. The mean cross-slope flow (Table II) for this

period of strong upwelling index ($\overline{UI}$=+125) is negative; if an extended Ekman layer is postulated, this cross-slope flow can be interpreted as lying within a layer which includes both meters. The magnitude of UI declines during the latter part of this period. On a shorter time-scale (about 9 days) the rise and fall of the upwelling index is accompanied throughout the record, beginning about 10 August, by poleward currents during periods of high upwelling index, and equatorward or diminished poleward currents during periods of reduced upwelling index. Thus, decreases in the upwelling index clearly relate to decreases in, or disappearance of, the counter current on these time scales (ca. 9 days), especially at the greater depth, 237 m.

In the following period, 24 November 1979 through 18 January 1980, as shown in Figure 24, the upwelling index is further reduced ($\overline{UI}$=-20), becoming dominantly negative after mid December. The meter at 194 m (Figure 24) is suspect due to lack of direction changes. This could be the result of a stuck vane, or a malfunction in the sensor. The alongshore current at depth 266 m alternates betweeen poleward and equatorward flows with durations between three and ten days. There is a marked change in currents after 23 December; they become weak and variable following a strong surge in the downwelling index at that time.

2. Anaylsis at Station 7

First consider the winter period January - February 1979, illustrated in Figure 8. The mean flow at both levels (152 m and 223 m) is predominantly poleward; but there are important event-scale variations. There are also alternating periods of positive and negative upwelling index during this period. The significant current variations and the upwelling index changes do not seem correlated. For example, from 5 to 10 January 1979 the currents at both depths were toward the southwest and during the next 15 to 17 days rotated clockwise. While the upwelling index varied erratically about zero, a similar rotation of the currents and unrelated variation of the upwelling index continued until about mid-February, when predominantly poleward flow again resumed, and the currents flowed in this direction for the remainder of the record, approximately twelve days. A fair conclusion for this period, when wind forcing is inconsistent and weak, is that there is no simple relation between the local upwelling index and the observed behavior of the currents on time scales of tens of days, and that some other mechanism than local forcing is involved.

During July and August 1979 (Figure 14), the index is positive and the flow at Station 7, is also predominatly poleward at 158, 231, and 356 m, especially in July. Large events involving reversals in the currents can be seen on

about 7 August and 24 August at all three observed levels. These events appear to occur at all depths almost simultaneously, which suggests that they are not directly related to the local wind.

During October and November 1979 (Figure 21) there is again a period of generally weak upwelling index when that index has no obvious relation to the currents. These currents were equatorward from 12 until to 30 October, followed by a reversal to become poleward from 1 through 21 November while the upwelling index again varied erratically near zero.

During the period 3 March through 12 April 1980 (Figure 27) poleward and equatorward flow alternate until about mid-March, while the upwelling index remains low. Following a rise in the upwelling index at that time (mid-March) and its persistence at high levels for nearly three weeks, predominantly poleward flow begins and persists for the remainder of the recorded period, some three weeks.

The meter at 113 m (Figure 27) is suspect due to lack of direction changes and small magnitude, and its data will be ignored.

3. Comparision of Stations 2 and 7

Current meter arrays were deployed at both Stations 2 and 7 during the period from 21 July to the end of August, providing an opportunity for examining horizontal

variations. As mentioned above, the currents at Station 2 (depicted in Figure 18) appear to respond with little or no lag to local forcing for this entire period. The response of the currents to local winds is not so clear at Station 7 (Figure 14). The currents at Station 7 may respond differently to local winds than currents at Station 2 because of the increased distance from the controlling boundary (coast). It is also possible that the response of the currents at Station 7 to local forcing may be masked by other influences. Certainly, there is no longer a nearly in-phase response of the current (note, for example, that on 27 August flow at Station 2 is predominantly poleward while flow at Station 7 is predominantly equatorward). If flow at Station 7 is being driven by local winds, the response must lag the wind.

Seasonally, the countercurrent was strongest during the spring months of 1979 at Station 2 (Figure 11). Geographically, the major discernable difference is the closer correlation between the current and the local forcing at Station 2 (inshore) than at Station 7 (offshore).

In summary, there are four important conclusions to the analysis of the currents and their relation to the upwelling index:

1. The entire record from January 1979 to April 1980 indicates currents are predominantly poleward at both stations, especially while Bakun's coastal upwelling index is high and positive.

2. Throughout the period, many events with time scales of tens of days occur at all recorded depths.

3. Current response to local forcing is more apparent at Station 2.

4. The countercurrent runs most strongly during the periods of high upwelling index at the nearshore station (Station 2).

B. SPECTRUM ANALYSIS

The current meter data are subjected to spectrum analysis in order to identify regions of high energy in the frequency domain, and consequently suggest forces at work in the study area.

The information from spectrum analysis, in this case via a program using Fast Fourier Transform (FFT), depends upon the record length and the sampling interval. The parameters used in the spectrum analysis program are:

Record length	$= TR = 1024$ h
Sampling interval	$= \Delta t = 1$ h
No. of points per record	$= N = 1024$
Resolution	$= \Delta f = .0098\ h^{-1}$
Nyquist frequency	$= f_N = .5\ h^{-1}$
No. of frequencies resolved	$= M = f_N/\Delta f = 512$
No. of degrees of freedom	$= N/M = 2$

The records available are typically about 50 days (1200 h) long; the maximum resolution attainable by FFT is, therefore, obtained from data sets of length 1024 hours.

For a fixed record length, however, high resolution is paid for at the expense of stability. The resolution with no averaging of spectral estimates over frequency is $\Delta f = 1024^{-1}\ h^{-1}$; and for single spectra (with no ensemble averaging) the estimates of variance have only two degrees of freedom (and are thus uncertain indicators of the variance distribution).

For time series defined at equal time-intervals Δt, the highest frequency component discernable is given by $N_f = (2\Delta t)^{-1}$, the "Nyquist frequency". The variance of frequencies higher than this are attributed, spuriously, to lower frequencies. Such misread ("aliased") variance is thought to be of minor concern in the data sets of this study except for those few (discarded) with high frequency instrumental noise. Among forces known to be at work in the ocean which are likely to contribute to energetic currents are tidal and (possibly) inertial forces. Some of the most important components are the semi-diurnal tide-producing forces (Sverdrup, et al., 1942):

Name	Symbol	Period(h)	Frequency(h^{-1})
Principal lunar	M_2	12.42	.0805
Principal solar	S_2	12.00	.0833
Luni-solar	K_2	11.97	.0835

The inertial frequency and period, calculated with the average latitude (35.8°) of Station 2 and Station 7, are $f(i) = .0487\ h^{-1}$, and $T(i) = 20.5$ h.

The spectral estimates consistently indicate energetic components at tidal and inertial frequencies as well as at periods of approximately 10 days. The dominant tidal components present are the semi-diurnal, with the most significant peaks appearing to be the luni-solar. In Table I are shown the approximate values of the low frequency, inertial, and semi-diurnal tidal peaks for both alongshore, and onshore/offshore motion. These values in Table I are taken from the spectrum analysis plots to show what, if any, relation there is between high energy and depth, season, and proximity of the shore. In general the spectra indicate greater energy for tidal, inertial, and low frequencies at the upper meters. It appears that motions at these frequencies are also more energetic in winter than in summer. Finally, tidal and low frequency energy are greater near shore, while energy in the inertial frequency is greater offshore.

C. INFERENCES FROM PROGRESSIVE VECTOR DIAGRAMS

The PVD's are helpful in observing low frequency variations and the mean currents which are summarized in Table II. As a meander, eddy, or wave in the countercurrent moves through a stations position the boundary between the poleward flow and equatorward flow moves about, with the current meters alternating between either side of that boundary. Such an occurrence is reflected in the PVD's as a current reversal.

TABLE I

COMPARISON OF HIGH ENERGY PEAKS (1000 CM. SQ. HOUR)

STATION	START DATE	DEPTH	LOW FREQ. (10 DAY)		INERTIAL		S.D. TIDAL	
			ALONG SHORE	ON/OFF SHORE	ALONG SHORE	ON/OFF SHORE	ALONG SHORE	ON/OFF SHORE
2	23 APR 79	169	5.3	0.5	1.0	0.5	8.0	6.5
		241	4.0	SMALL	1.0	0.5	11.0	5.0
2	21 JUL 79	165	17.0	0.5	1.0	0.3	3.0	1.7
		237	8.0	0.5	SMALL	0.2	3.0	1.2
2	24 NOV 79	194*	0.3	0.5	SMALL	SMALL	SMALL	0.1
		266	45.0	1.0	2.0	1.0	11.0	17.0
7	5 JAN 79	152	6.8	7.0	1.8	2.3	1.8	2.0
		223	1.5	5.4	0.6	0.5	1.4	0.8
7	7 JUL 79	158	2.6	17.0	0.2	SMALL	1.6	2.0
		231	2.0	5.1	0.4	SMALL	1.3	1.8
		356	0.8	1.0	0.9	0.7	0.5	0.6
7	7 OCT 79	127	1.0	1.6	4.5	3.4	3.7	3.8
		200	1.3	1.1	2.0	2.3	3.0	2.6
7	3 MAR 80	113*	0.2	0.1	0.1	0.1	0.3	0.1
		186	1.8	1.1	1.4	1.5	2.6	2.0
		311	0.9	0.2	1.8	1.8	5.0	1.2

S.D. = Semi-Diurnal
* = Meter is suspect

TABLE II

COMPARISON OF MEAN CURRENT AND TEMPERATURE

STATION	TIME PERIOD	DEPTH	$\overline{\theta}$ (azim. °T)	$\overline{V}$ (cm/sec)	$\overline{T}$ (° cent.)	$\overline{V}'$ (cm/sec)	$\overline{U}'$ (cm/sec)
2	23 APR 79 thru 16 JUN 79	169 241	341.2 340.4	16.0 11.1	8.5 8.0	+16.0 +11.1	+ 0.34 + 0.08
2	21 JUL 79 thru 13 SEP 79	165 237	325.1 314.3	6.1 1.5	9.0 8.5	+ 5.89 + 1.35	- 1.57 - 0.65
2	24 NOV 79 thru 18 JAN 80	194* 266	279.8 003.1	6.2 2.7	9.0 8.0	+ 3.08 + 2.48	- 5.38 + 1.06
7	9 JAN 79 thru 28 FEB 79	152 223	354.8 16.6	4.6 4.3	9.4 8.6	+ 4.58 + 3.84	+ 0.39 + 1.93
7	9 JUL 79 thru 30 AUG 79	158 231 356	312.2 330.6 338.6	4.5 5.8 2.8	8.7 8.3 7.4	+ 3.56 + 5.47 + 2.74	- 2.76 - 1.93 - 0.55
7	9 OCT 79 thru 29 NOV 79	127 200	68.1 70.6	5.1 4.1	9.3 8.4	+ 1.05 + 0.67	+ 4.99 + 4.05
7	4 MAR 80 thru 15 APR 80	113* 186 311	310.5 328.7 8.2	4.4 3.4 2.7	9.0 8.0 7.0	+ 3.40 + 3.17 + 2.56	- 2.80 - 1.24 + 0.84

$\overline{U}'$ = Mean cross-slope current
$\overline{V}'$ = Mean alongshore current
* = Meter is suspect

Two interesting features readily seen in the progressive vector diagrams Figures 47 through 62, are current reversals of long duration, and the mean current for the duration of the mooring. The mean current direction (θ), given as azimuth, speed (V), cm-s^{-1}, and temperature (T), degrees Celsius, for each current meter for the entire study period are shown in Table II; and they are also shown on the individual plots. Also shown in Table II are the mean onshore and alongshore current components repectively. The alongshore direction in this case is defined as 340° T for Station 2, and 350° T for Station 7, which represent the azimuths of the mean contours at those sites.

For both Stations 2 and 7 over the entire period, the seasonal and depth variations will be considered. The mean alongshore current is always poleward at all observed levels (from 127 m to 356 m) and at both stations. Mean alongshore current speeds were greater nearshore at Station 2, than offshore at Station 7. Mean alongshore current speed at the upper levels appears to vary only slightly seasonally at both stations, approximately 4 to 6 cm-s^{-1}, with the exception of the upper meter at Station 2, 23 April to mid-June, i.e., the counter current appears weak at observed depths, except in late spring.

The PVD's indicate predominantly unidirectional flow at the near-surface levels of Station 2,. while at the deeper,

lower meters there were often current reversals and oscillations possibly associated with meanders, waves, and eddies. Current reversals occurred in greater numbers and were present at all depths at Station 7 which may possibly be due to Station 7 being near a boundary between north and south currents. The semidiurnal components of the currents are at times apparent in the PVD's as for example in Figures 49 and 57.

Shorter term variations are also indicated by the PVD's, in particular reversals. No apparent current reversals are present at the upper meter of Station 2, 24 April to mid-June (Figure 49), and only two minor reversals can be seen near the end of the record for the lower meter (Figure 50). At the same station from 23 July to mid-September, two current reversals of short duration are evident at the upper layer (Figure 54); and more than half a dozen current reversals of from three to twelve days in duration can be seen for the current at greater depth (Figure 55). Current reversals are not present at the upper level of Station 2 (Figure 58), 27 November 1979 to mid-January 1980, but several current reversals of approximately three to nine days duration can be seen at depth (Figure 59).

A single current reversal is present at both meters of Station 7 (Figures 47 and 48), 9 January to the end of February 1979. At the same station, 9 July to the end of

August 1979, three current reversals are apparent at the upper two meters (Figures 51 and 52), and two reversals can be seen in the lower meter (Figure 53). These reversals all appear to be of a relatively long duration, 15 to 20 d. Two current reversals are present at both meters of Station 7 (Figures 56 and 57), 9 October to 29 November 1979. For the period 4 March to 15 April 1980 at the same station, no reversals are seen in the upper meter (Figure 60), but several oscillations and reversals are seen in the two lower meters (Figures 61 and 62).

D. CROSS-SLOPE CURRENT

The mean cross-slope currents from Table II are plotted against time in Figure 5. The dominant feature of these currents is an annual variation with onshore flow in winter months and offshore in spring and summer. This annual variation correlates with the strong upwelling occurring in the spring and summer, and the weak upwelling index in the winter.

Qualitatively, the relation between the upwelling index and the cross-slope current means is consistent with a thick layer influenced by a modified surface Ekman regime.

E. TIME SERIES

The time series plots of U (positive-east) and V (positive-north) components were primarily used as an aid in interpreting the stickplot data. They are also useful for their resolution of high frequency variations. The

semidiurnal components of the currents are evident as well as the larger scale current oscillations indicated in the stickplots.

The temperature versus time plots also indicate the semidiurnal components and large-scale oscillations found in the stickplots. Approximate mean temperatures for the current meters at Station 2 and 7 throughout the record are shown in Table II. The temperature decreased with depth at all stations. The mean temperatures at Station 2 at all depths (Figure 6) become increasingly warmer during the period from April 1979 to January 1980, while the mean temperatures at Station 7 at all depths (Figure 7) become increasingly cooler. This is consistent with existing wind stresses, which would tend to uplift the isotherms at the nearshore station (Station 2) in the spring (strong upwelling index) and depress them in winter (weak upwelling index). The cooling continues at Station 7 at all depths from December 1979 until April 1980, and no simple explanation is apparent.

IV. CONCLUSIONS

A northward flowing current was found for the entire period of this study. It was strongest at the upper levels, roughly between 100 and 200 m. Seasonally, this countercurrent was strong during spring and substantially weaker during winter. The speed and direction of the countercurrent at any given time may differ markedly from the average flow. There were events on scales of tens of days which appeared to be qualitatively coherent between stations and also between depths at a given station. Frequent current reversals and oscillations occurred, consistent with the weak, poorly defined, broad flows associated with eastern boundary currents.

Bakun's coastal upwelling index is an indicator of possible wind-driven coastal upwelling. The coastal upwelling index is, in the mean, consistent with the observations of a deep cross-slope flow (Ekman layer), a large upwelling index corresponding to thickening of the Ekman layer. The countercurrent is present during the entire study, and the low frequency alongshore current is never equatorward.

Relatively high-energy peaks at semidiurnal tidal frequencies and inertial frequencies occurred in the

majority of the current records. Additionally, low frequency energy peaks were found at periods of about 10 d.

At Station 2, (nearshore), the alongshore component of these three frequencies tends to be greater than the on/offshore component, and generally speaking, the low frequency energy peak (T = 10 d) is dominant. At Station 7 (offshore), the on/offshore component of these three frequencies is noticeably greater, but there is no obvious pattern to the energy distribution.

The countercurrent was present at the study site, but it was not possible to unequivocally identify and correlate local forcing with the countercurrent. The vertical migration of the frontal boundary between equatorward and poleward flow was observed at both stations, but less often at the nearshore Station 2 than at Station 7. Hydrographic data from the study area for this time period were not examined at all, and deserve future consideration. Correlation of currents and wind or upwelling index, comparision of observed currents with predicitons of various models, and the relation of metered currents to those inferred from hydrographic data are recommended for future studies.

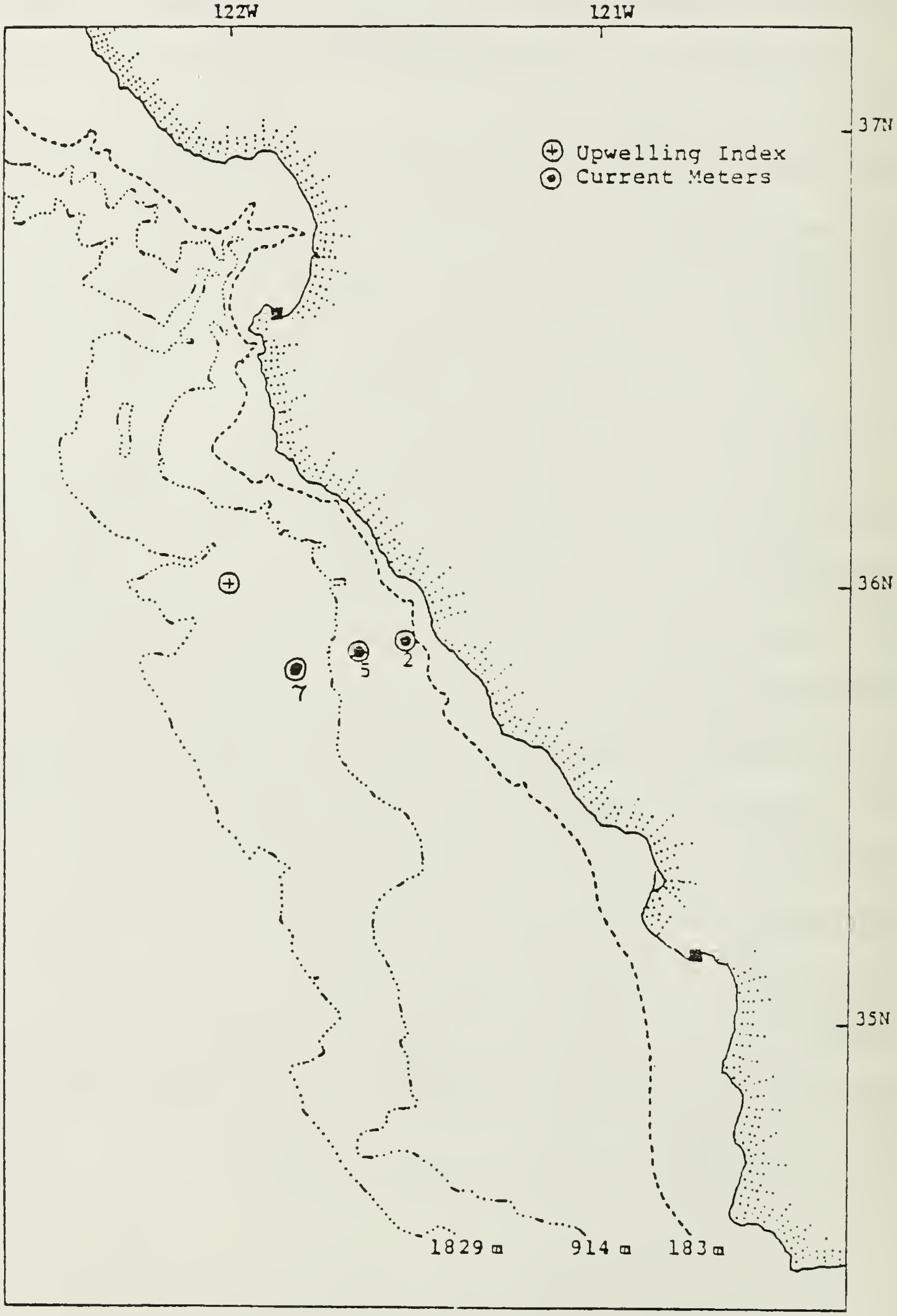


Figure 1. The study area.

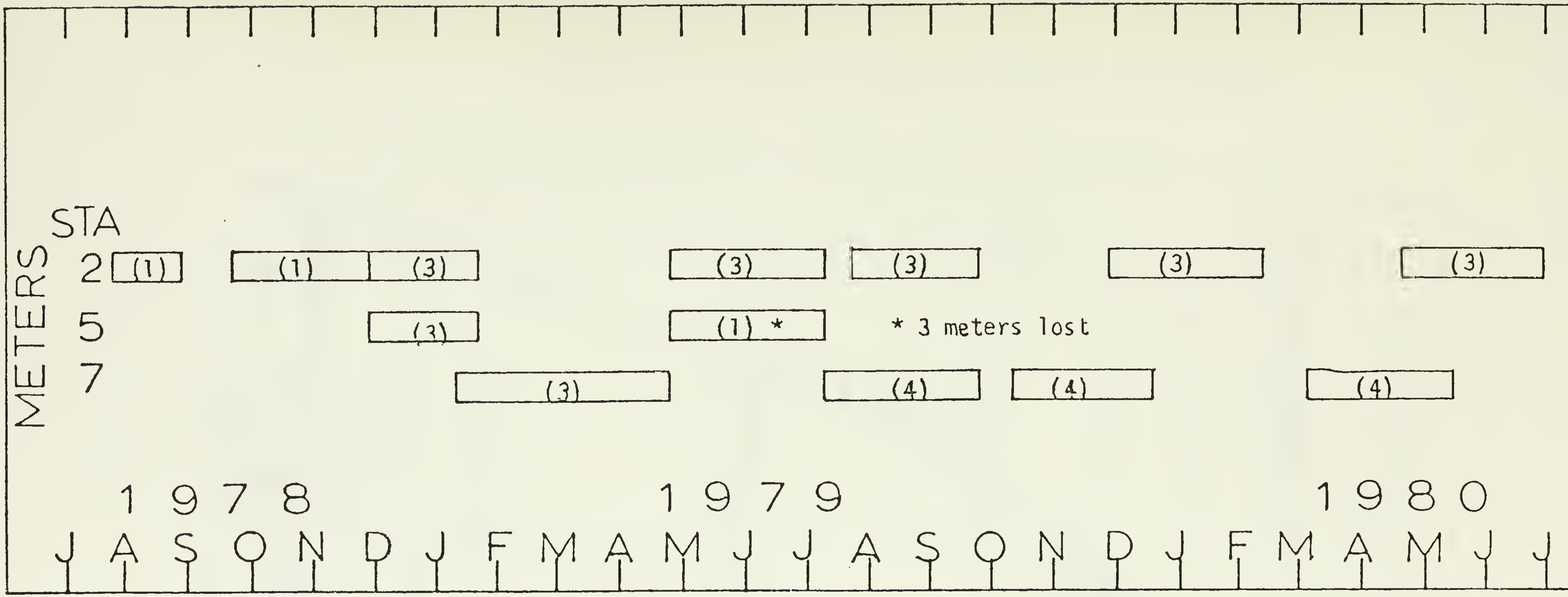


Figure 2. Chronology of current meter deployment.

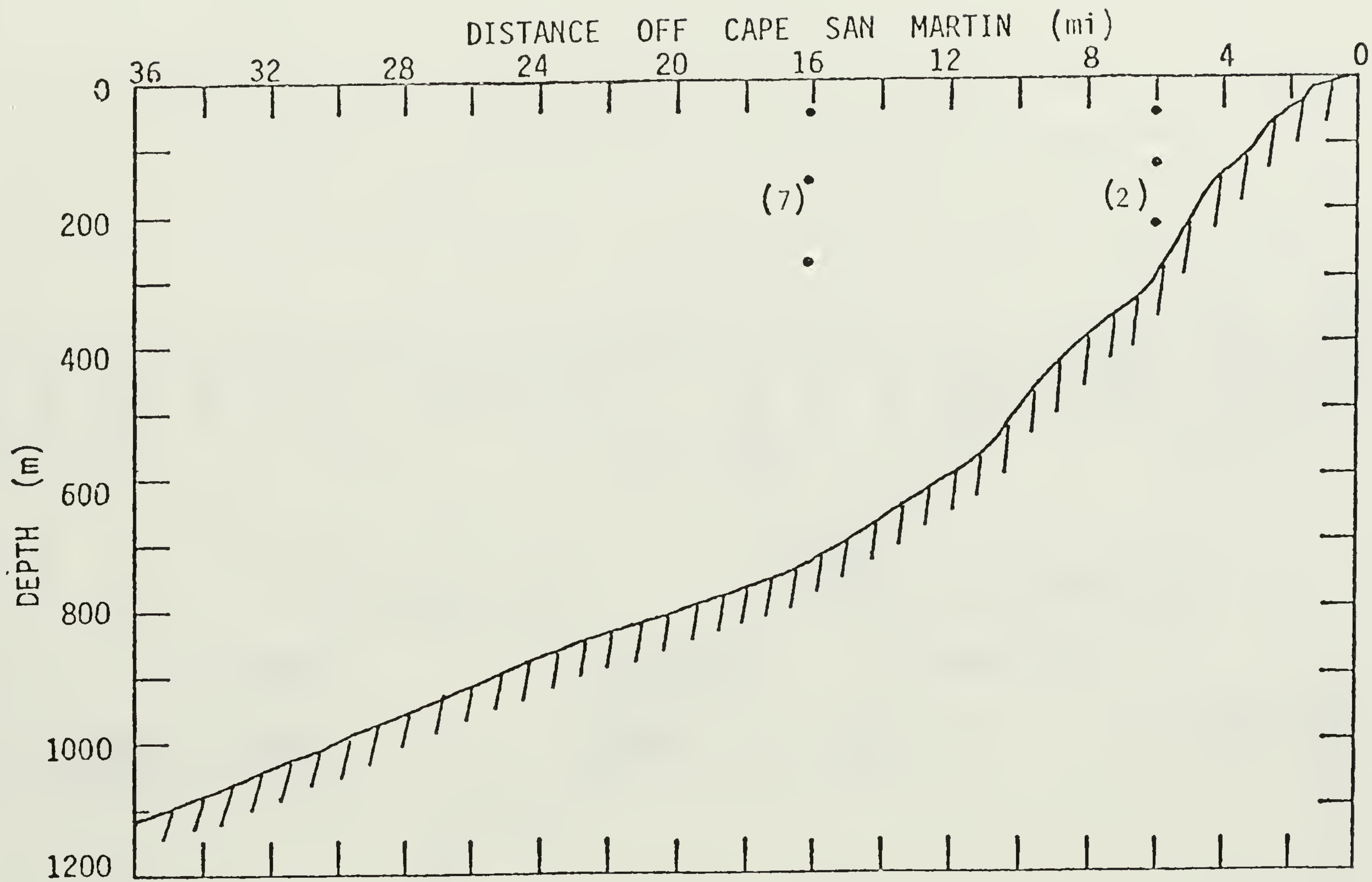


Figure 3. Vertical section showing representative locations of current meters off Cape San Martin, California.

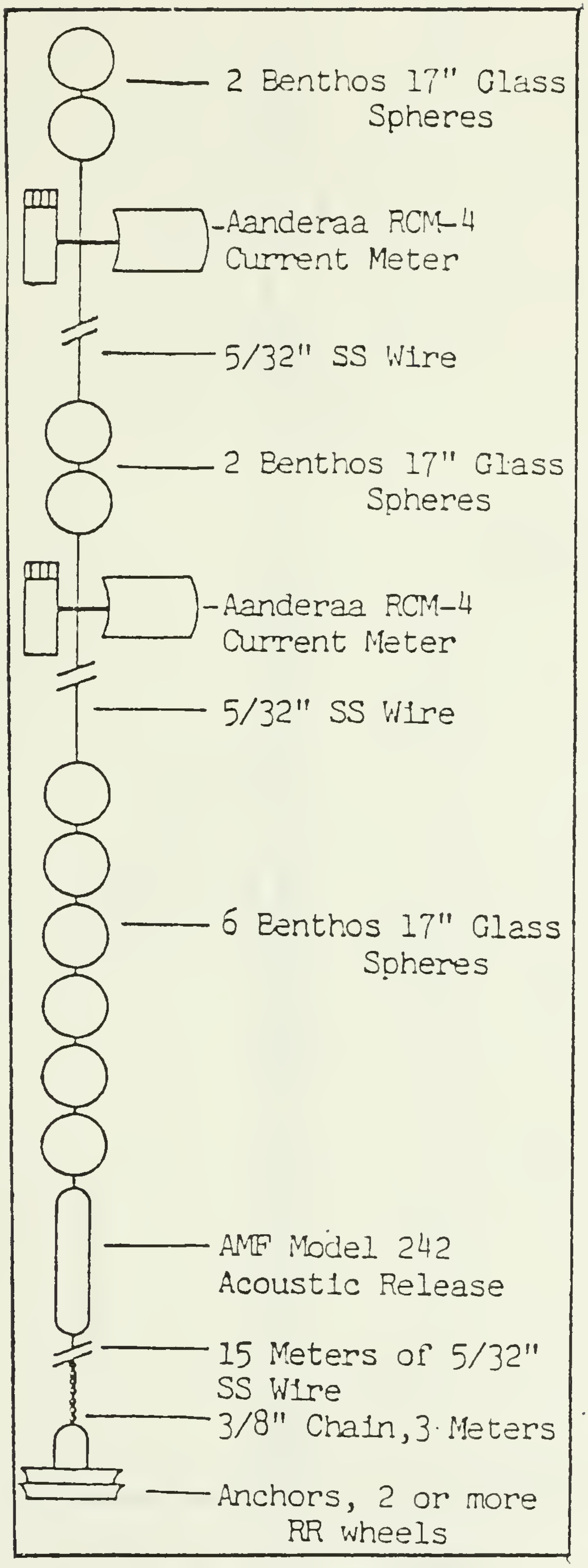


Figure 4. Current meter array.

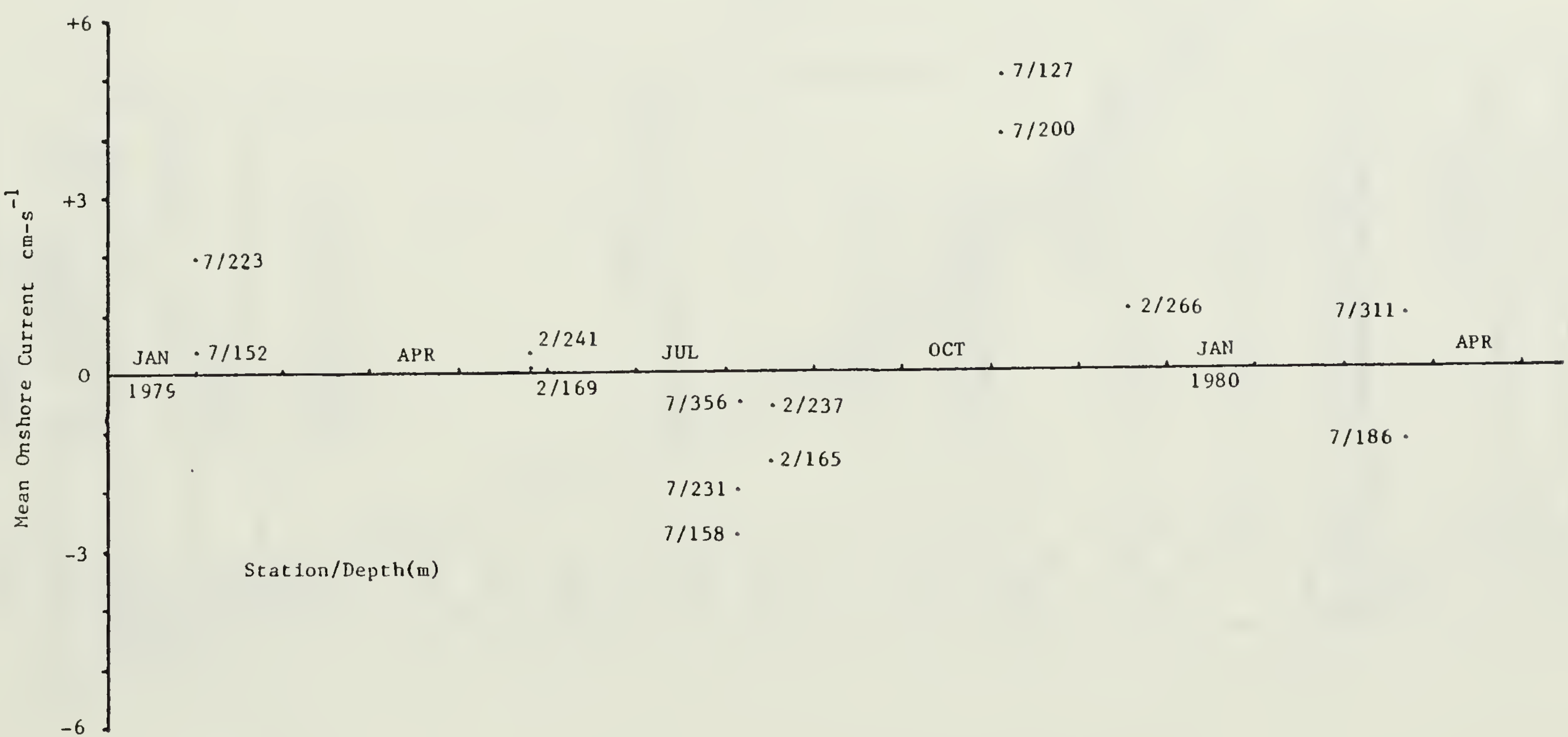


Figure 5. Mean onshore currents.

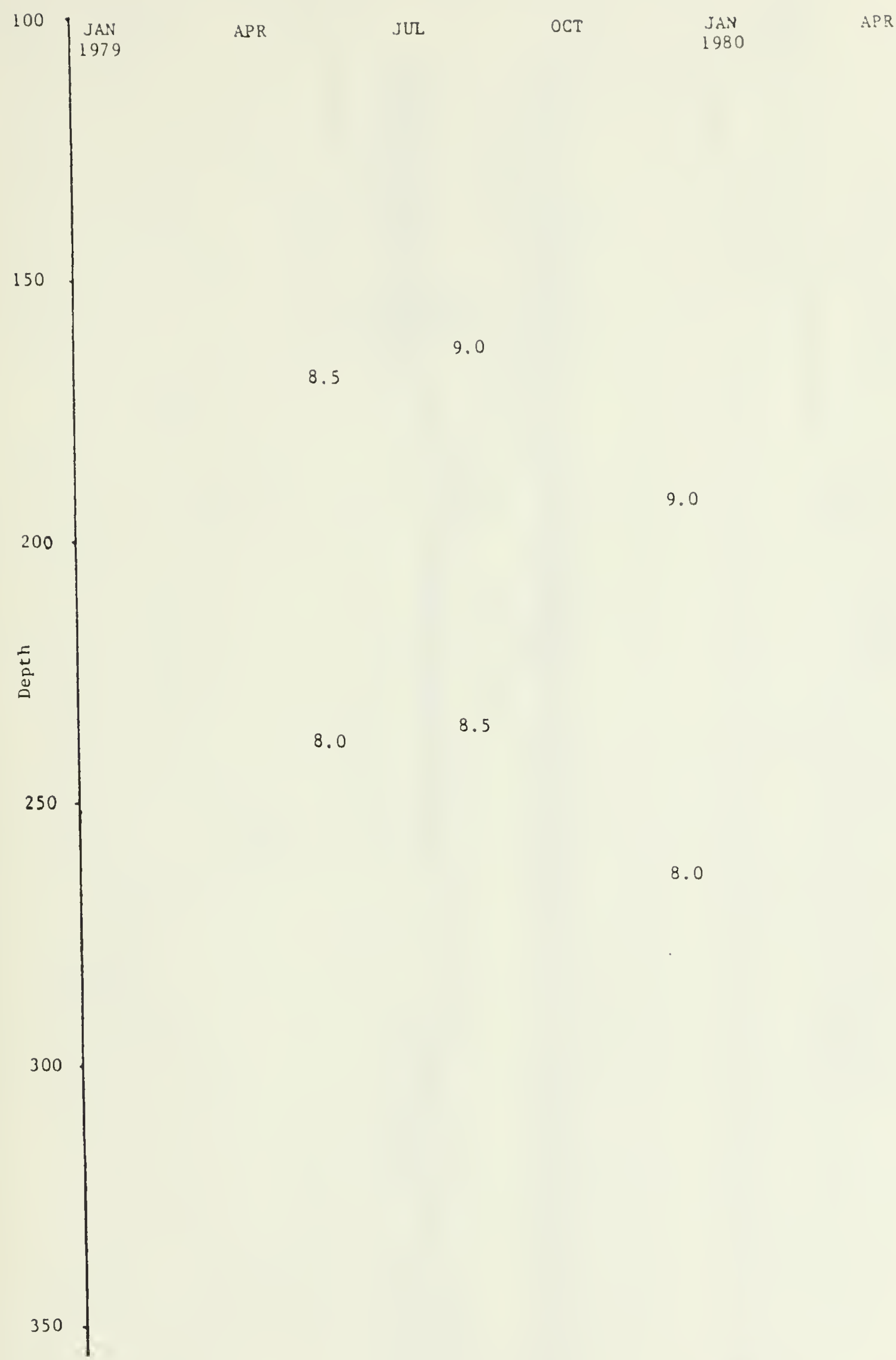


Figure 6. Mean temperatures at Station 2.

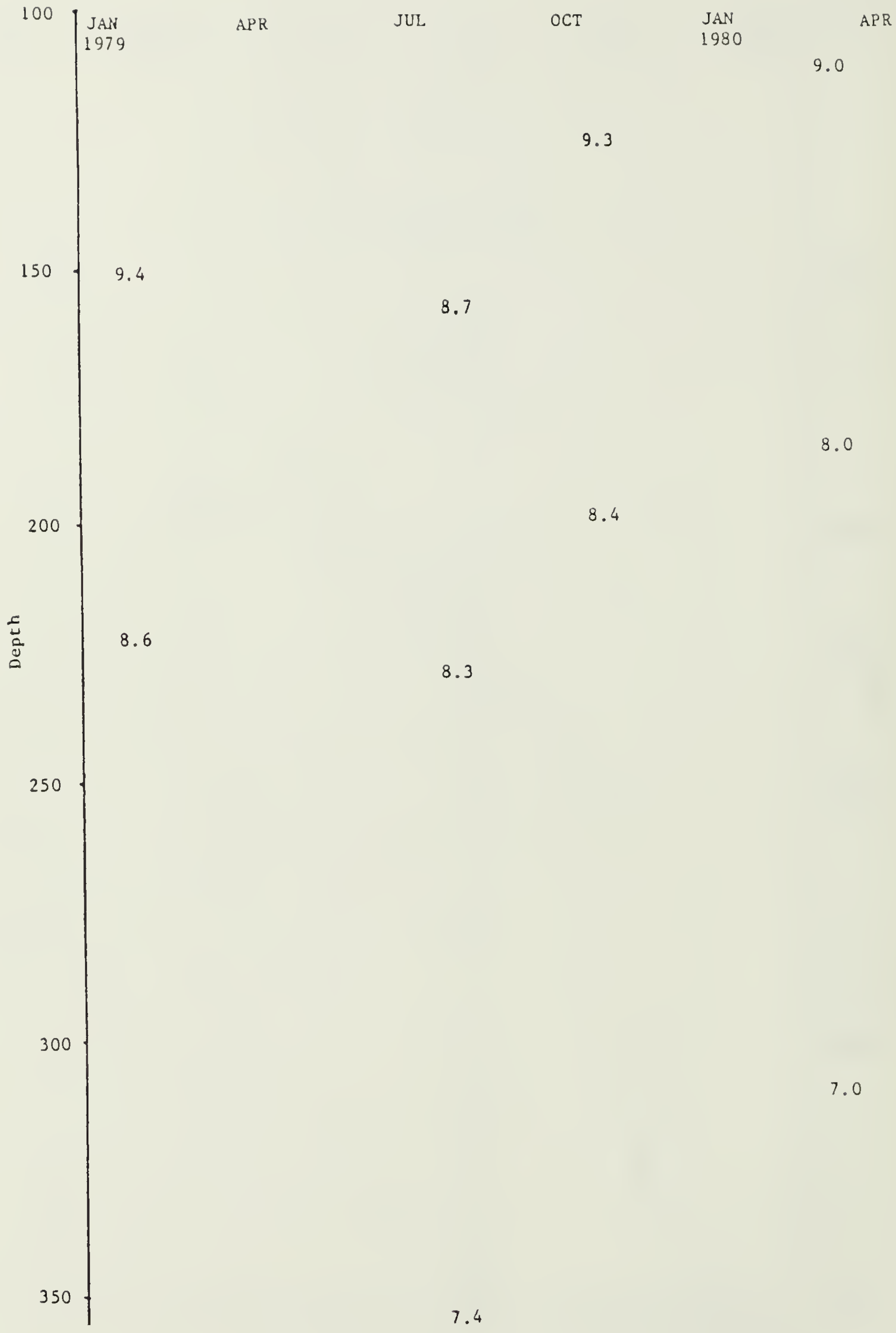


Figure 7. Mean temperatures at Station 7.

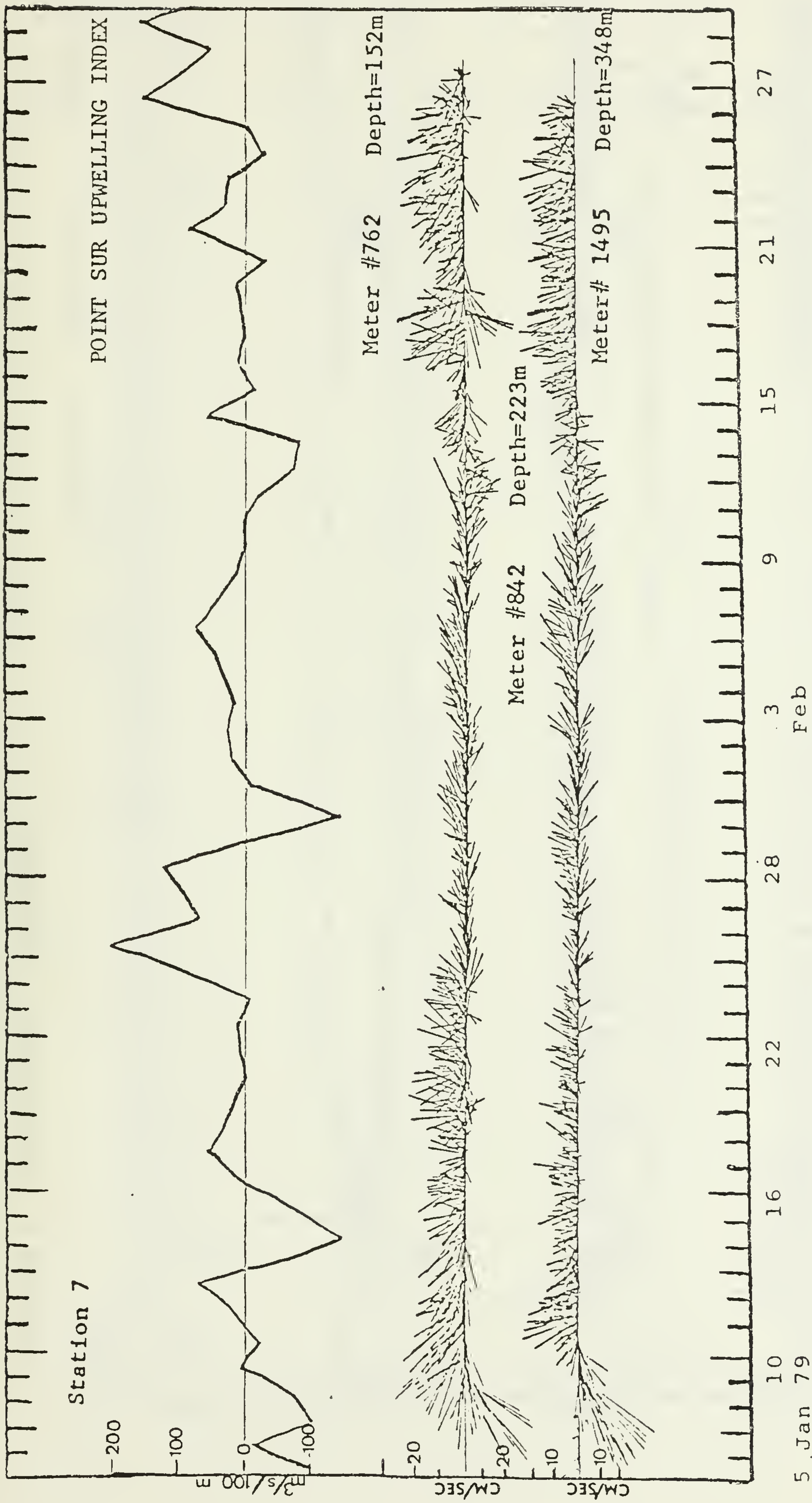


Figure 8. Point Sur Upwelling Index and stickplots of hourly current vectors for the current meters at Station 7 deployed on 5 January 1979.

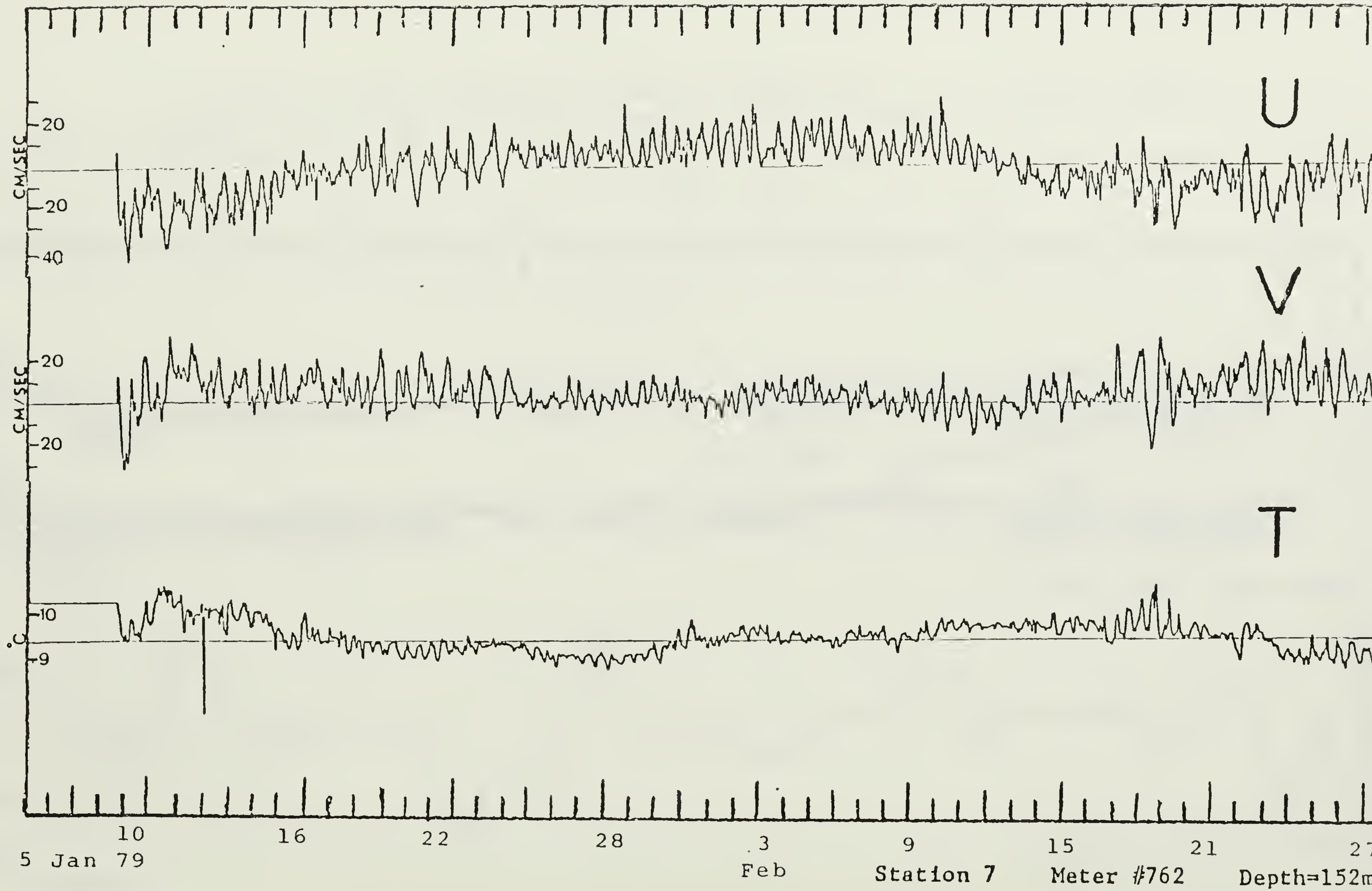


Figure 9. U component, V component, and temperature plots versus time for the current meter at 152 m depth at Station 7 deployed on 5 January 1979.

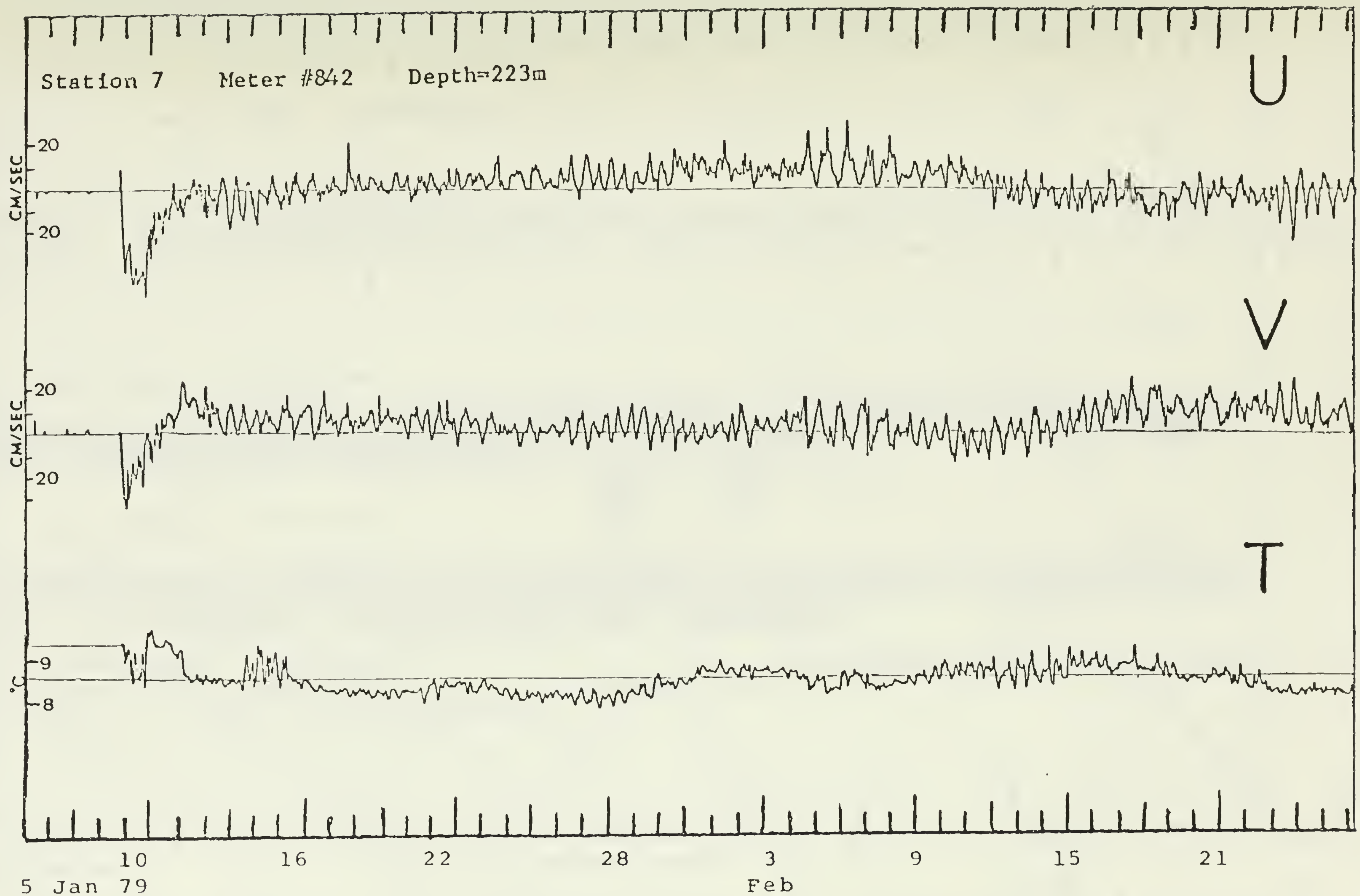


Figure 10. U component, V component, and temperature plots versus time for the current meter at 223 m depth at Station 7 deployed on 23 April 1979.

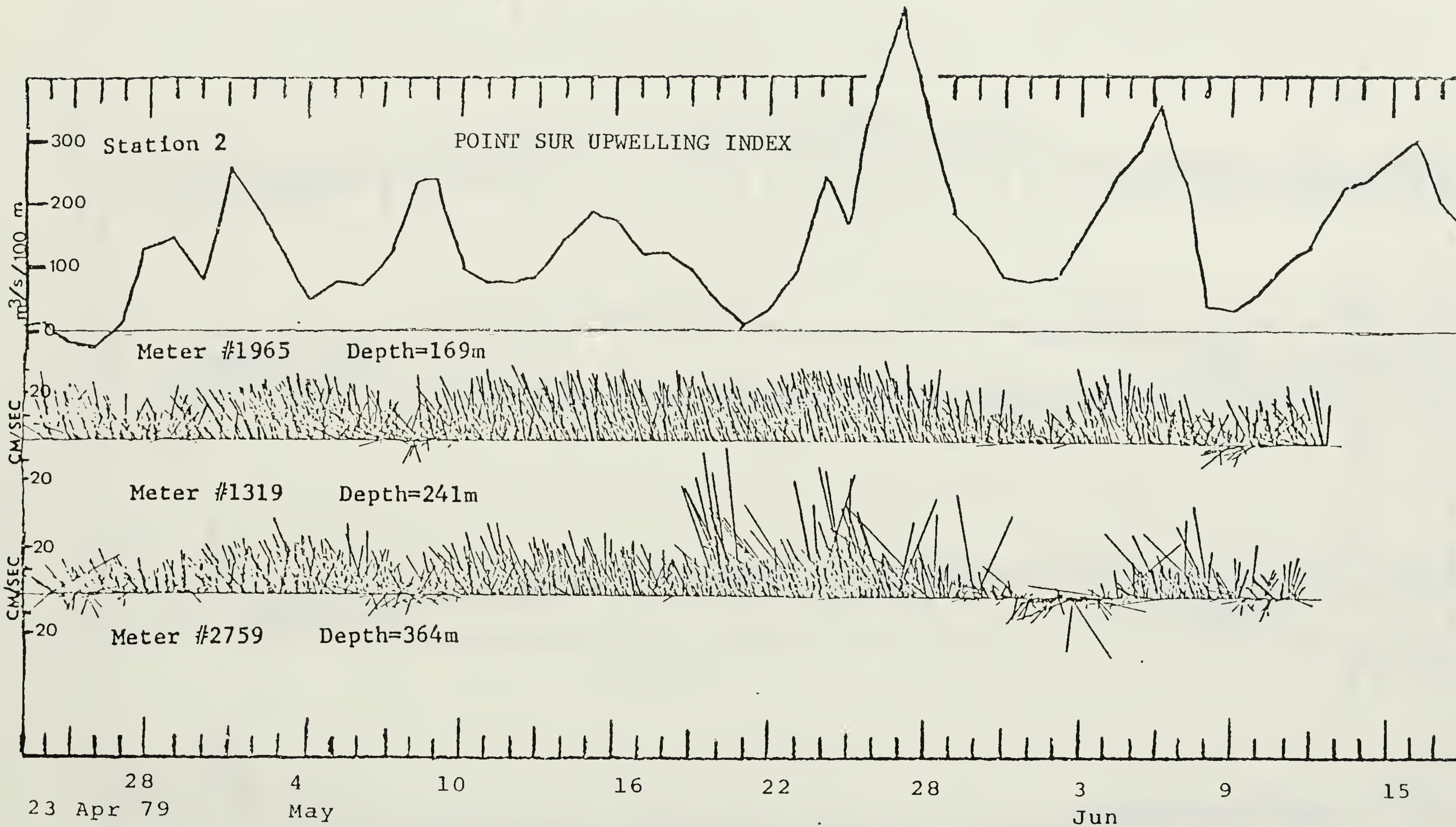


Figure 11. Point Sur Upwelling Index and stickplots of hourly current vectors for the current meters at Station 2 deployed on 23 April 1979.

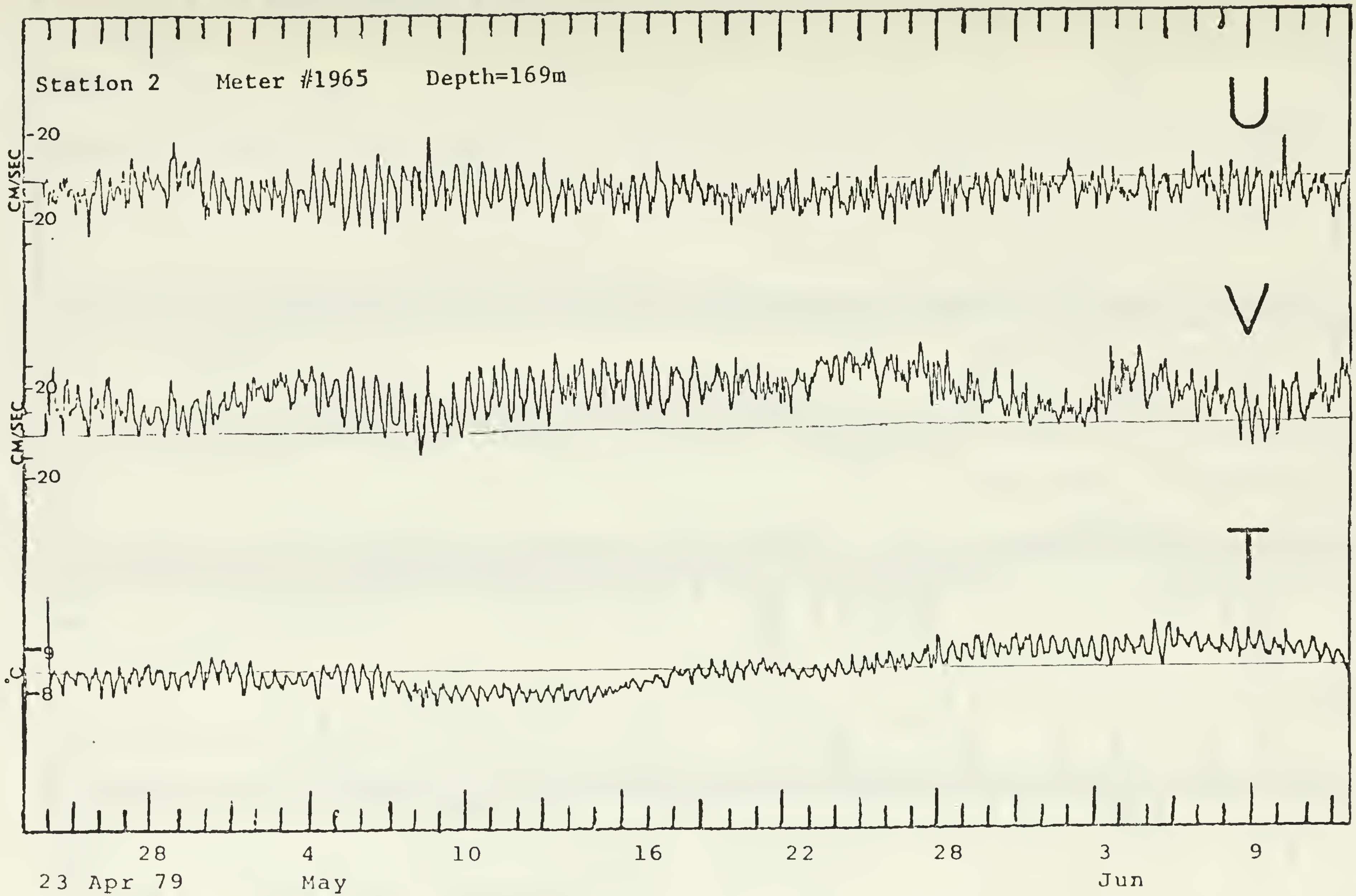


Figure 12. U component, V component, and temperature plots versus time for the current meter at 169 m depth at Station 2 deployed on 23 April 1979.

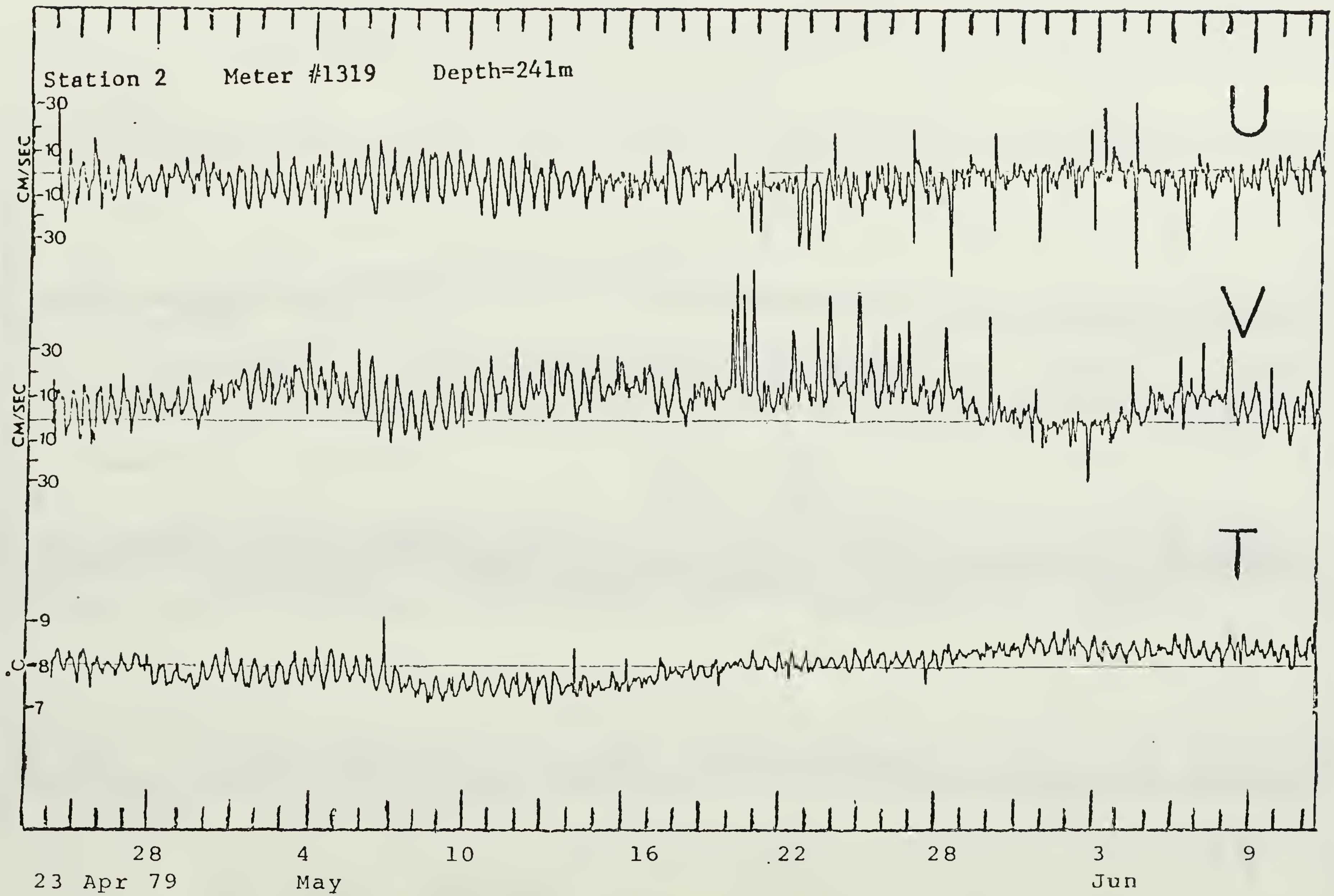


Figure 13. U component, V component, and temperature plots versus time for the current meter at 241 m depth at Station 2 deployed on 23 April 1979.

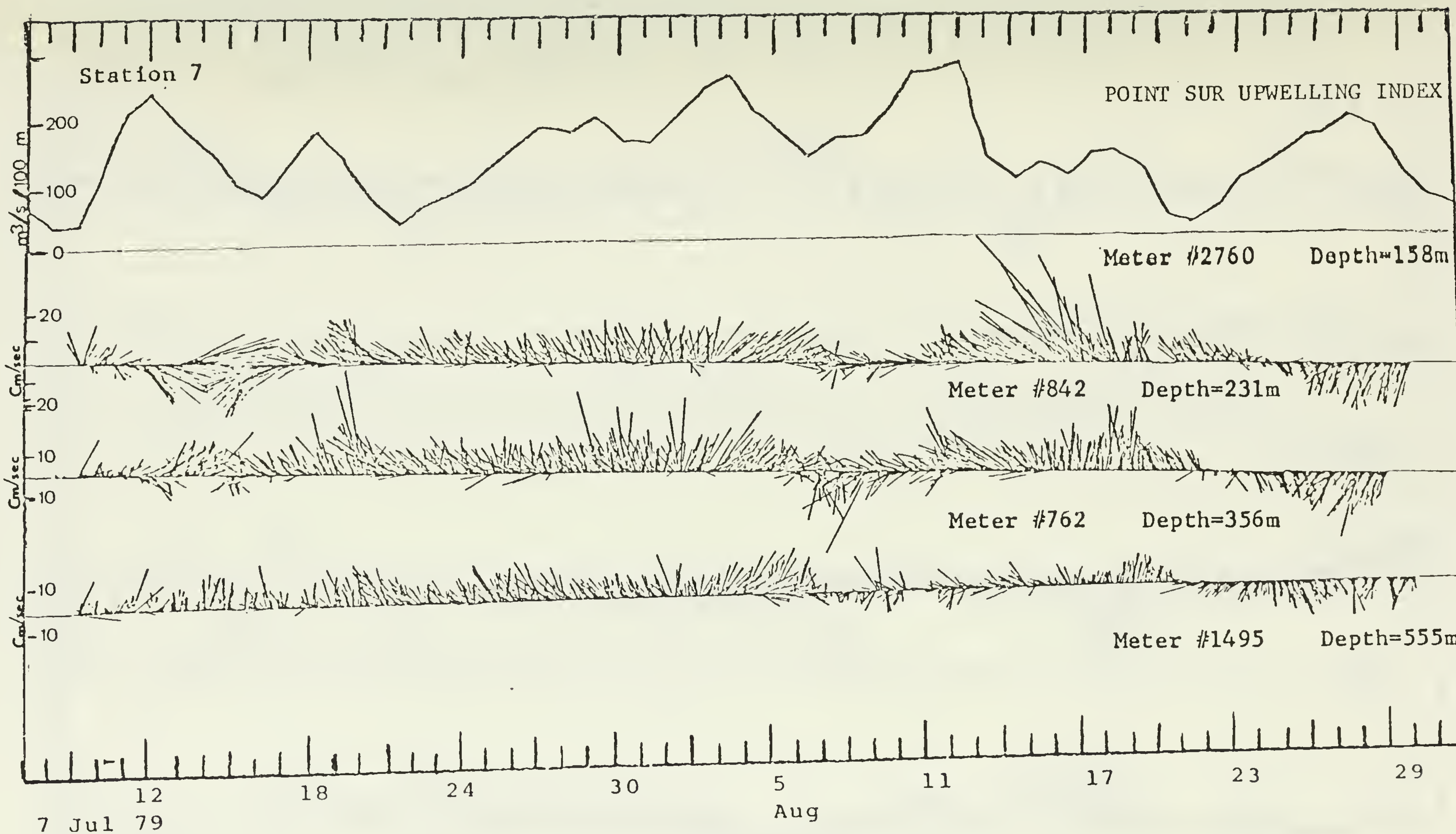


Figure 14. Point Sur Upwelling Index and stickplots of hourly current vectors for the current meters at Station 7 deployed on 7 July 1979.

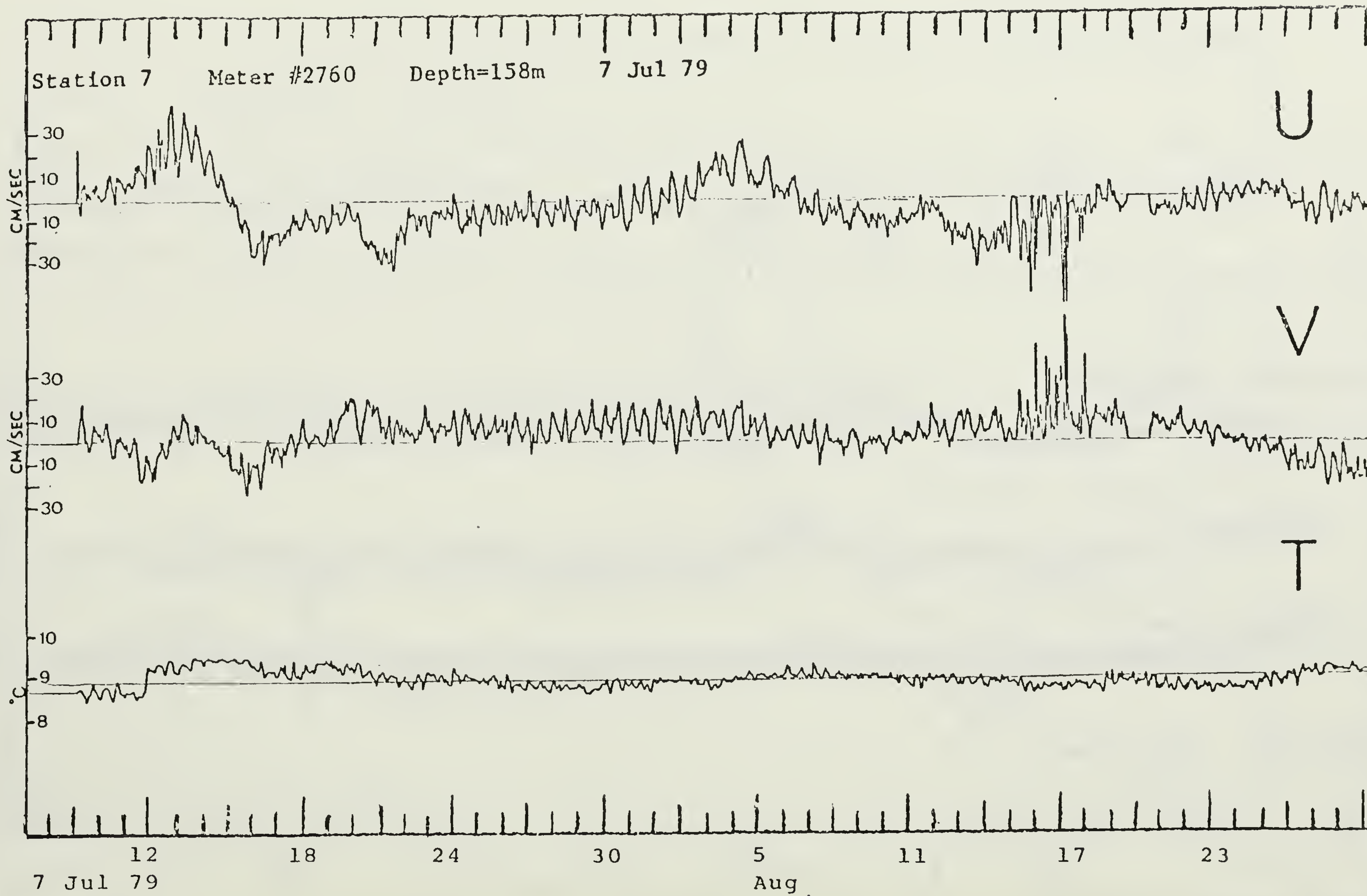


Figure 15. U component, V.component, and temperature plots versus time for the current meter at 158 m depth at Station 7 deployed on 7 July 1979.

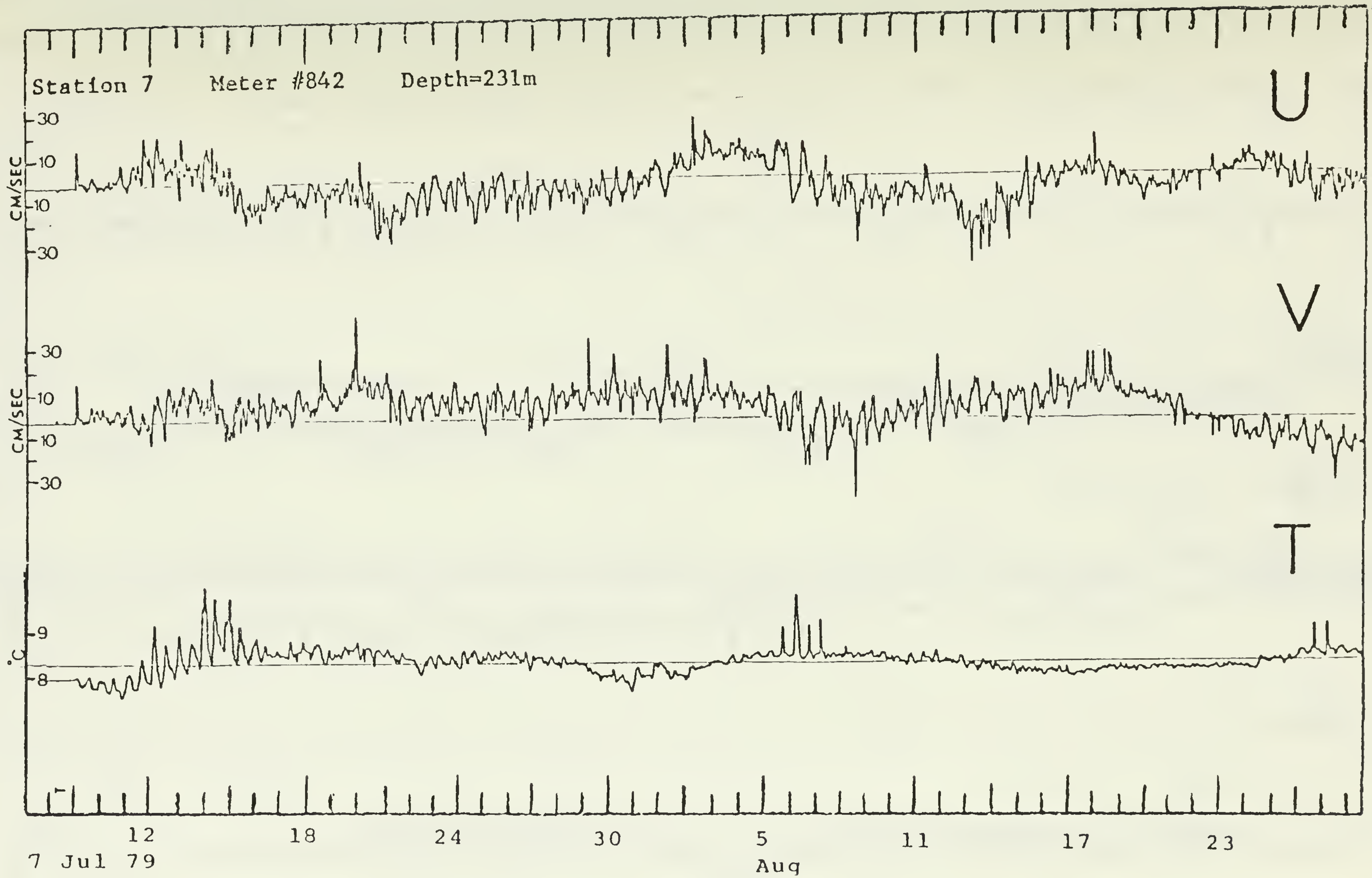


Figure 16. U component, V component, and temperature plots versus time for the current meter at 231 m depth at Station 7 deployed on 7 July 1979.

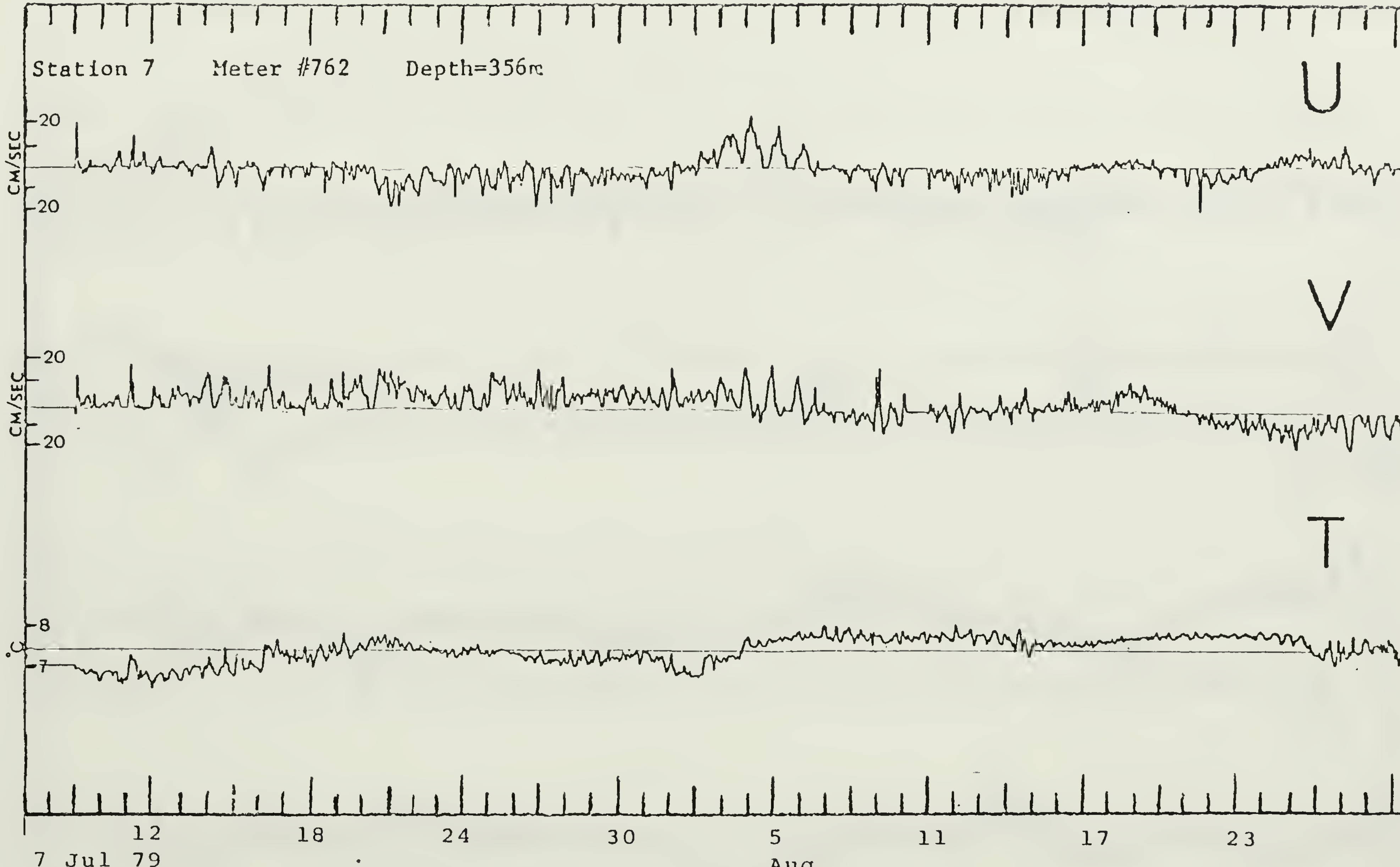


Figure 17. U component, V component, and temperature plots versus time for the current meter at 356 m depth at Station 7 deployed on 7 July 1979.

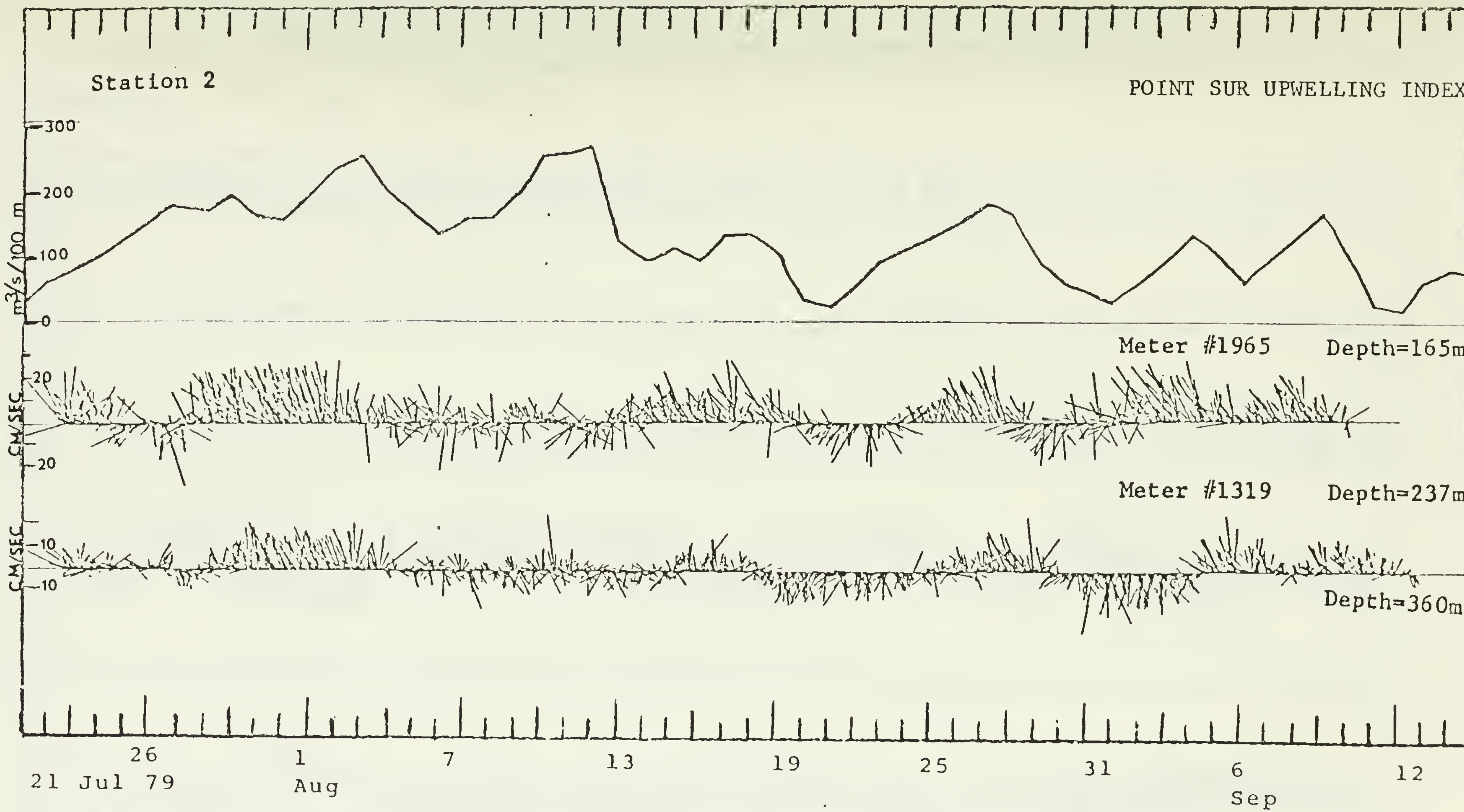


Figure 18. Point Sur Upwelling Index and stickplots of hourly current vectors for the current meters at Station 2 deployed on 21 July 1979.

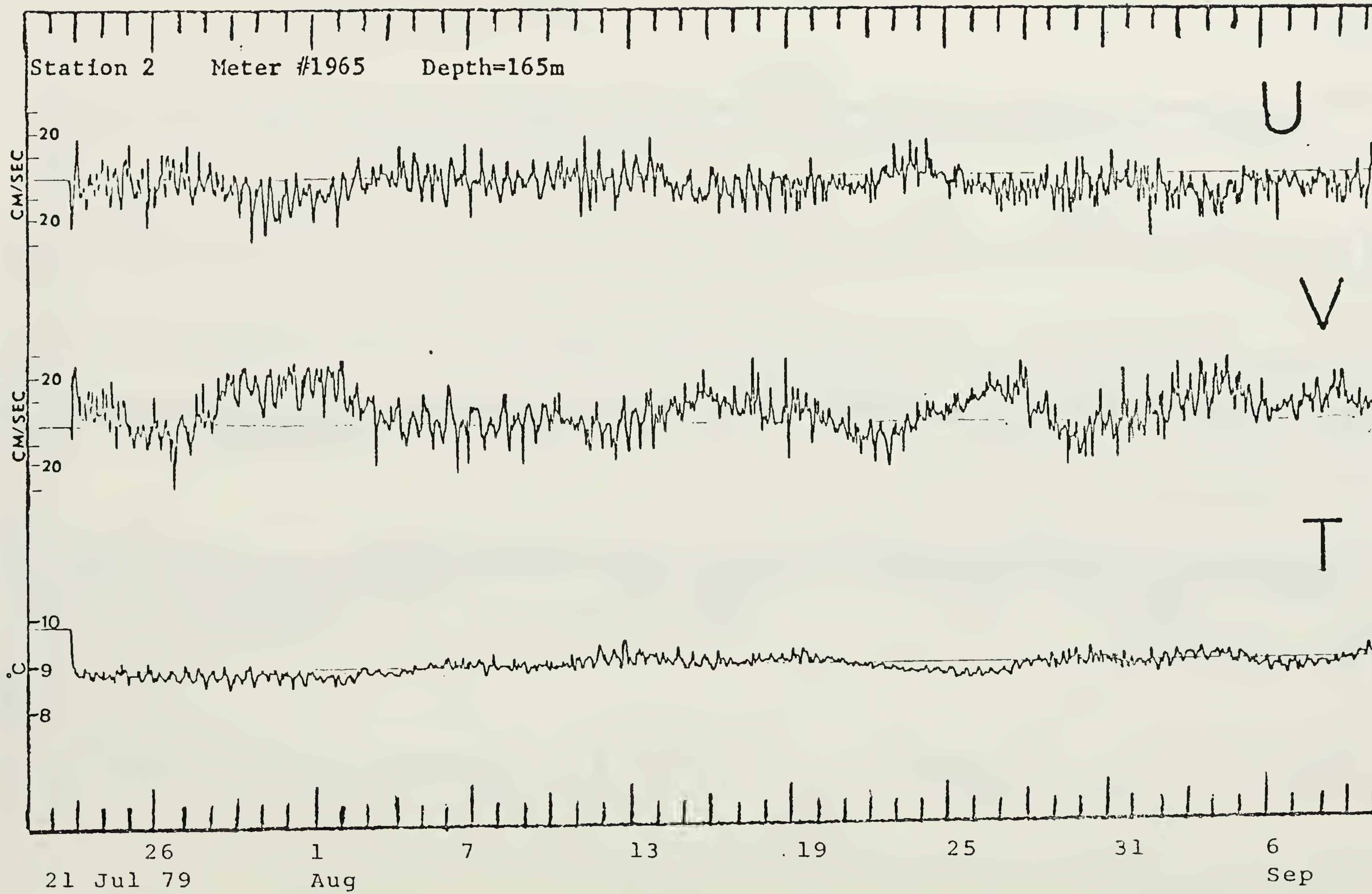


Figure 19. U component, V component, and temperature plots versus time for the current meter at 165 m depth at Station 2 deployed on 21 July 1979.

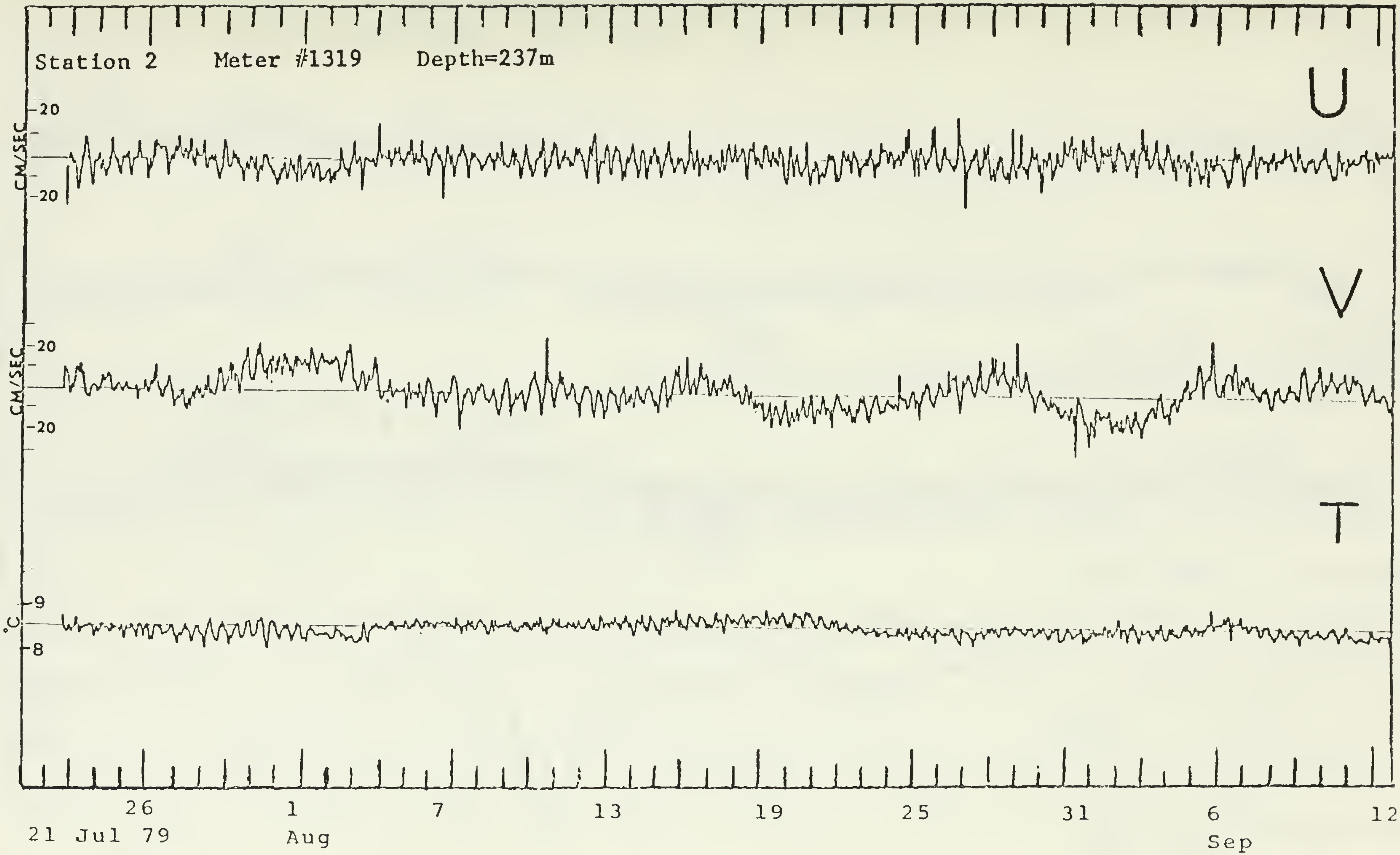


Figure 20. U component, V component, and temperature plots versus time for the current meter at 237 m depth at Station 2 deployed on 21 July 1979.

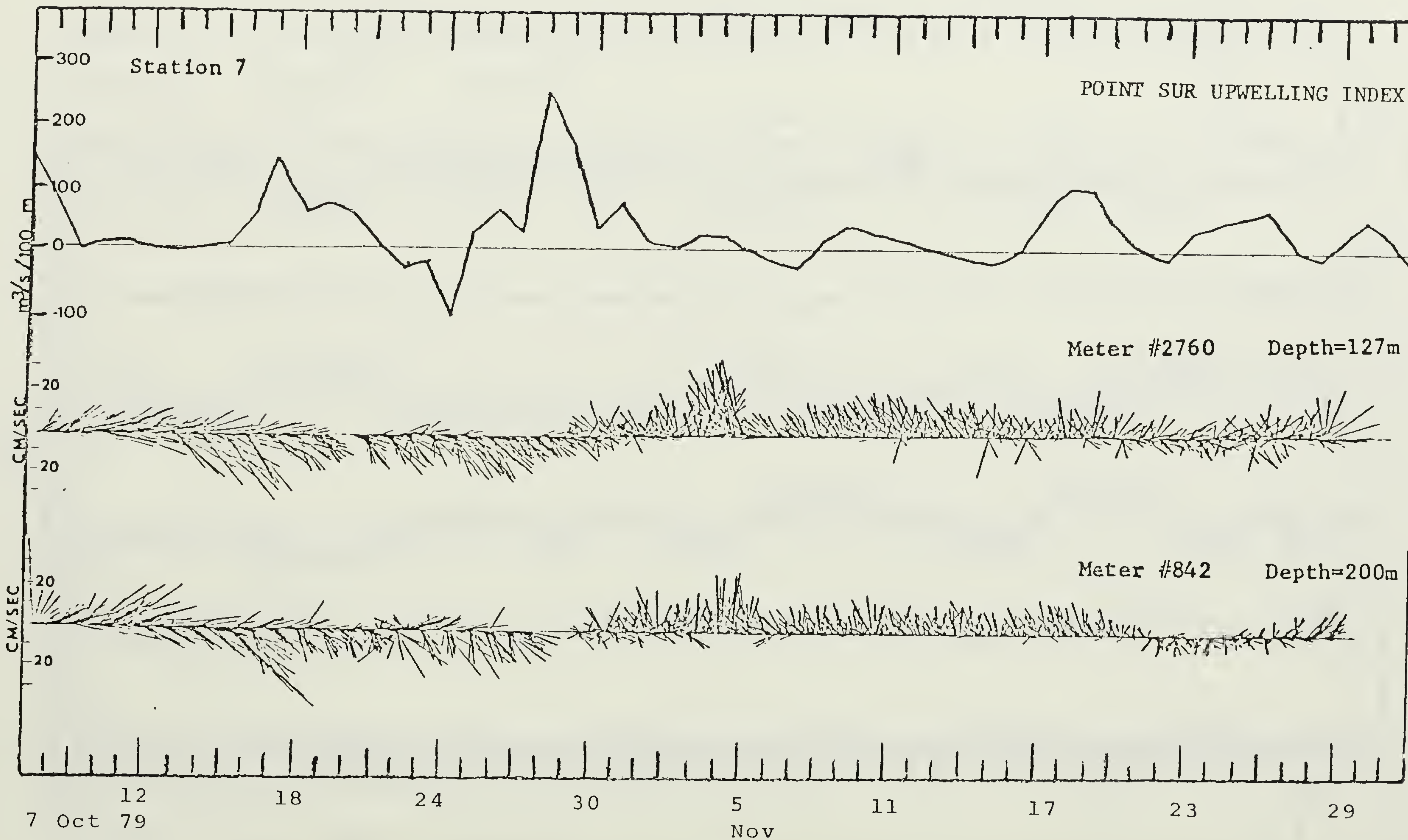


Figure 21. Point Sur Upwelling Index and stickplots of hourly current vectors for the current meters at Station 7 deployed on 7 October 1979.

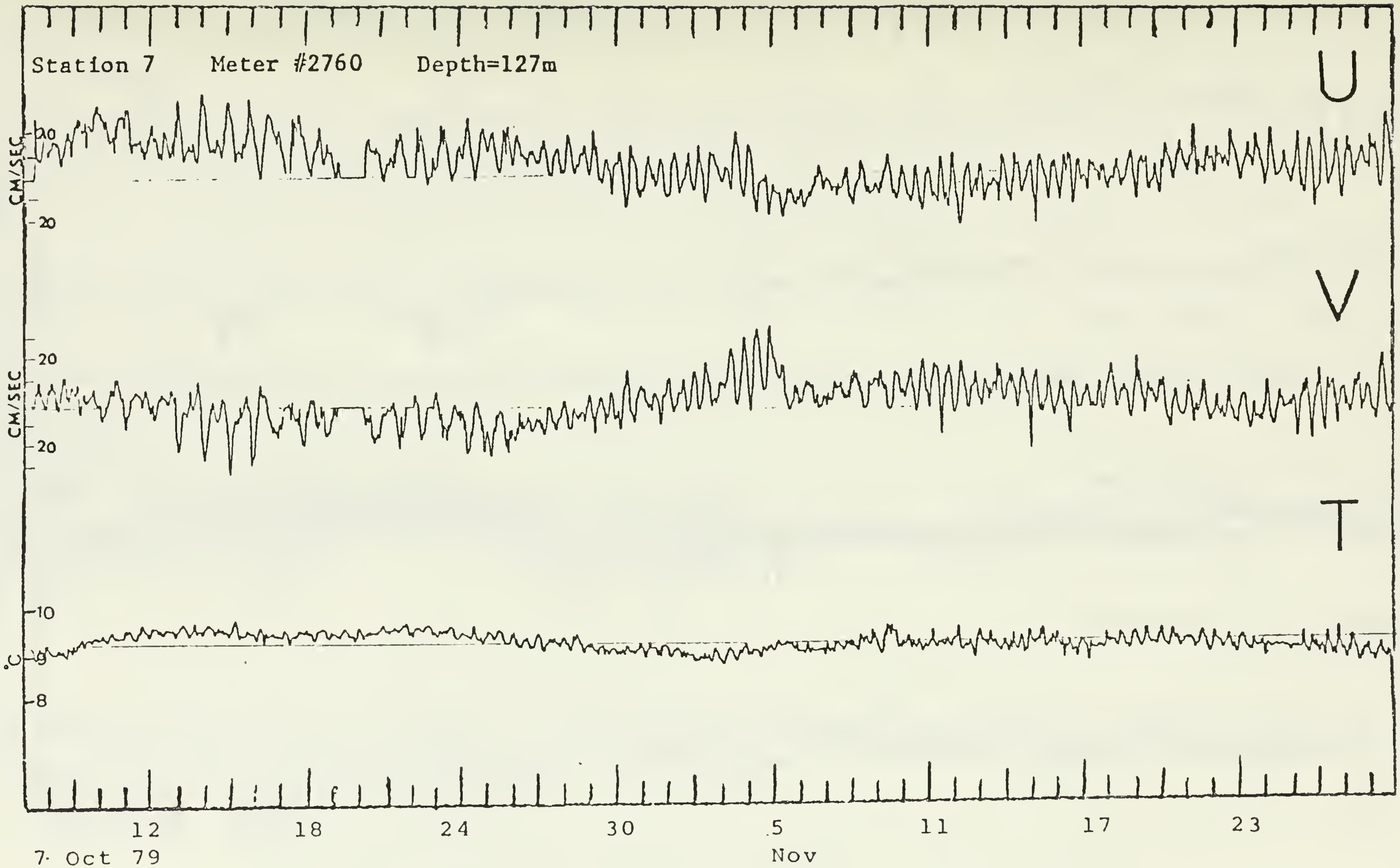


Figure 22. U component, V component, and temperature plots versus time for the current meter at 127 m depth at Station 7 deployed on 7 October 1979.

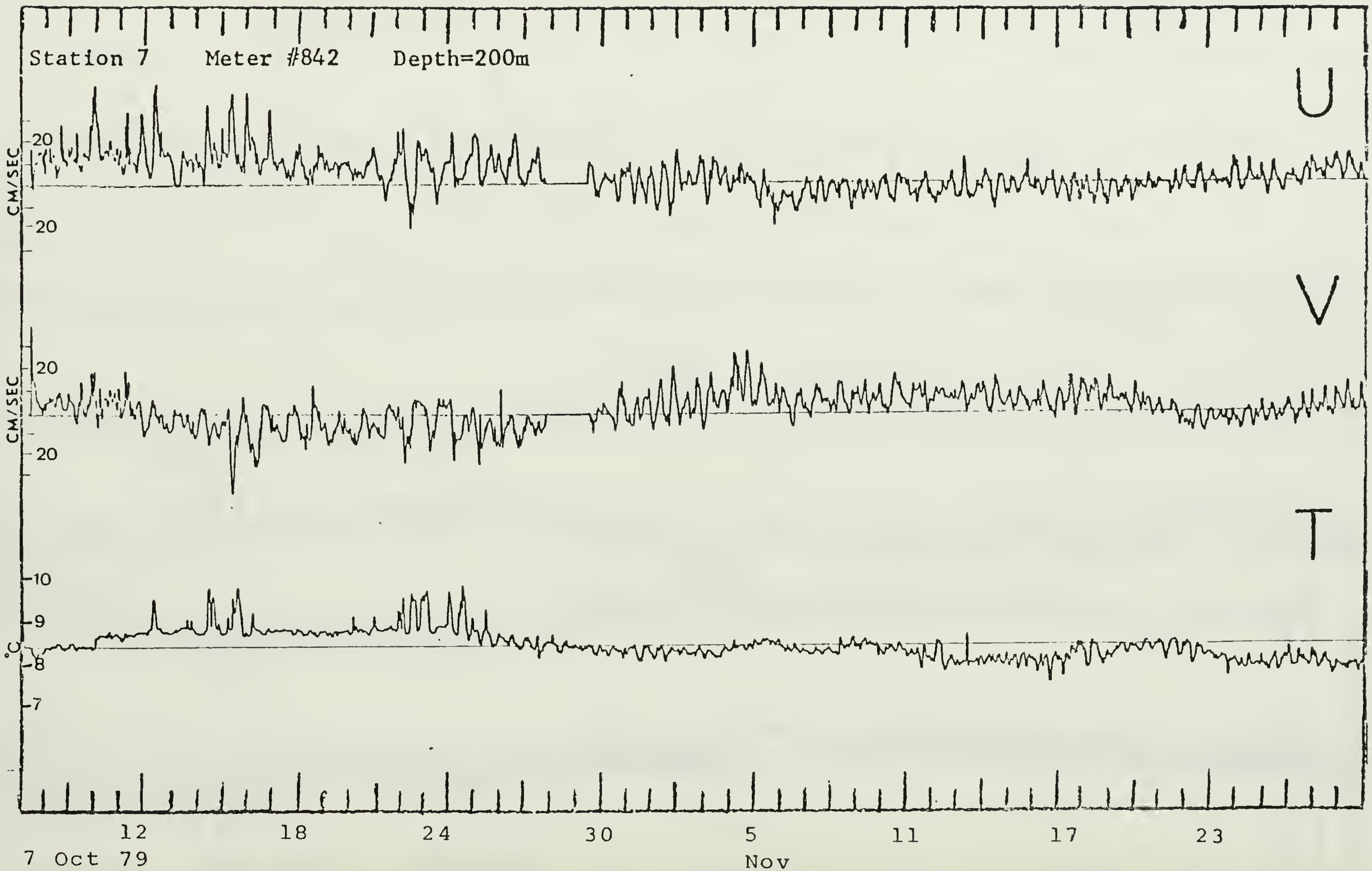


Figure 23. U component, V component, and temperature plots versus time for the current meter at 200 m depth at Station 7 deployed on 7 October 1979.

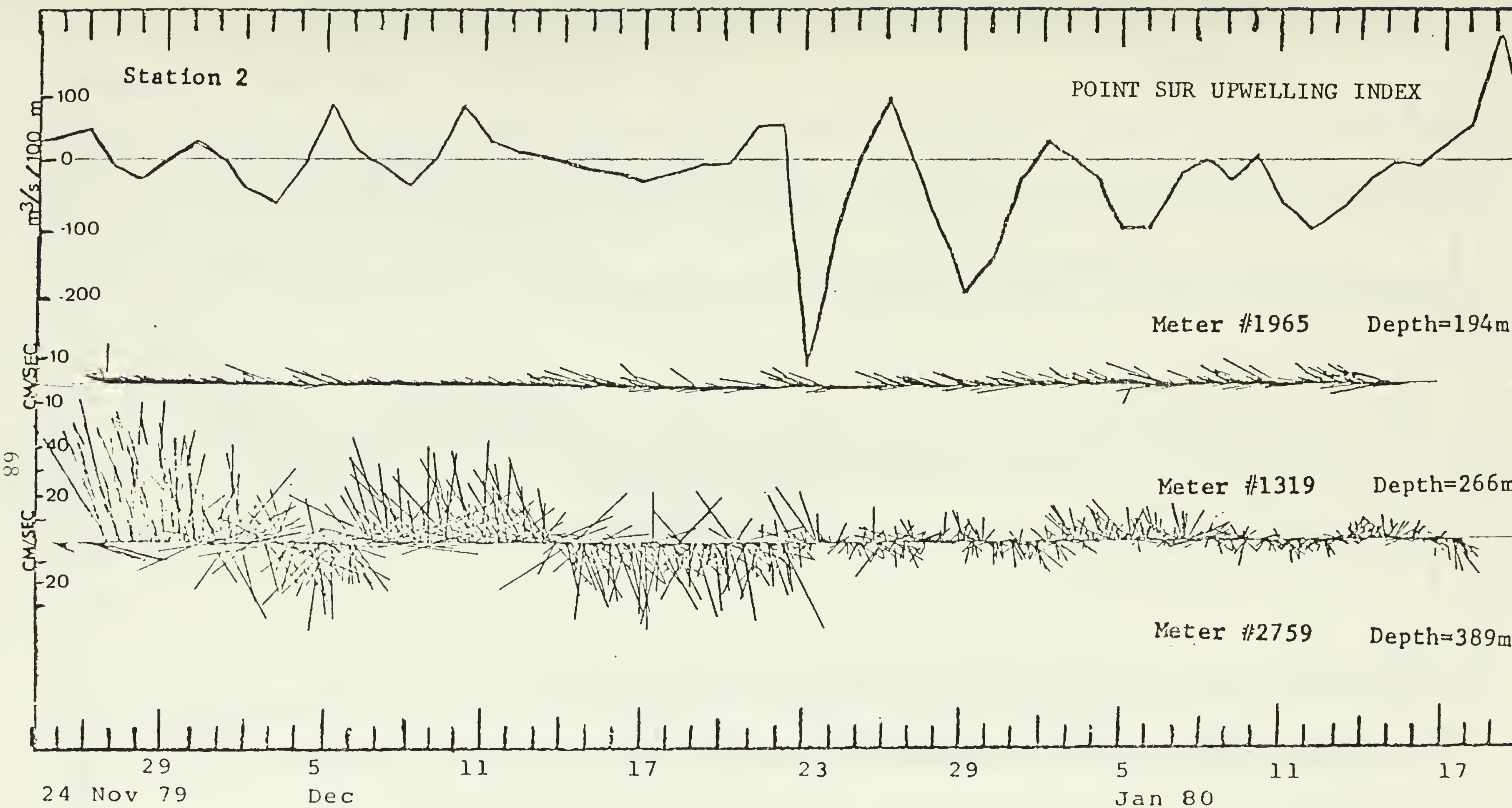


Figure 24. Point Sur Upwelling Index and stickplots of hourly current vectors for the current meters at Station 2 deployed on 24 November 1979.

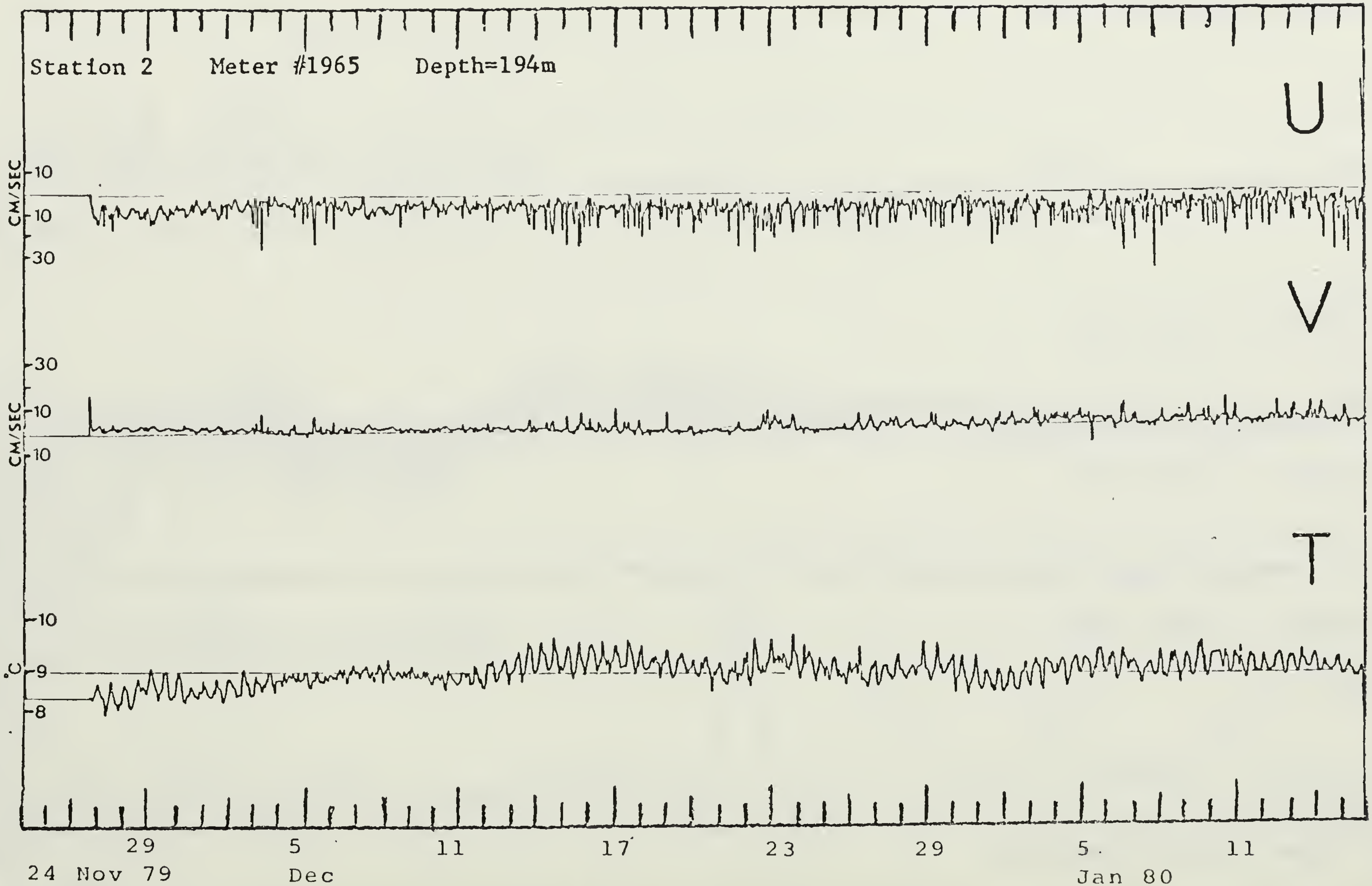


Figure 25. U component, V component, and temperature plots versus time for the current meter at 194 m depth at Station 2 deployed on 24 November 1979.

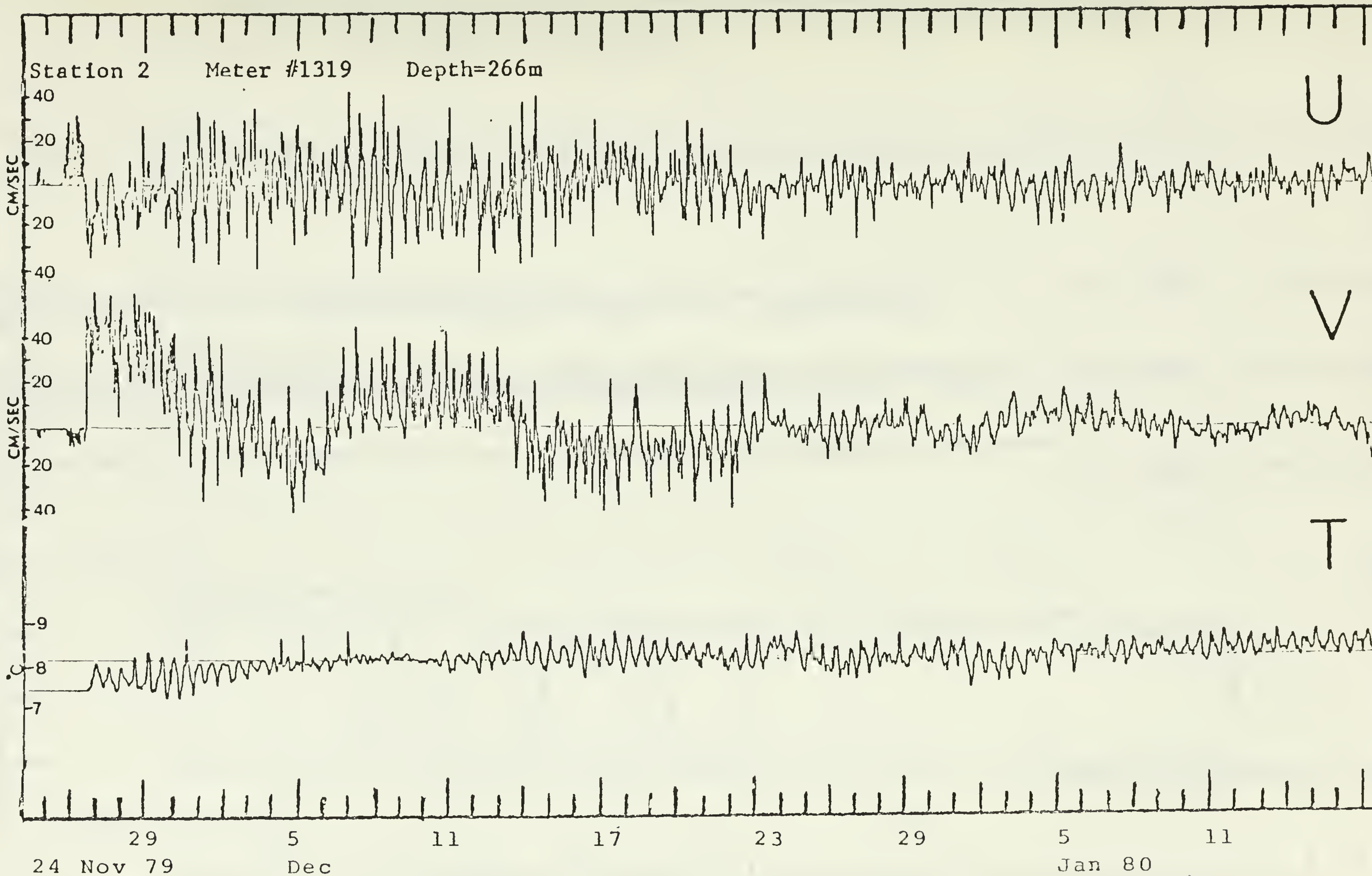


Figure 26. U component, V component, and temperature plots versus time for the current meter at 266 m depth at Station 2 deployed on 24 November 1979.

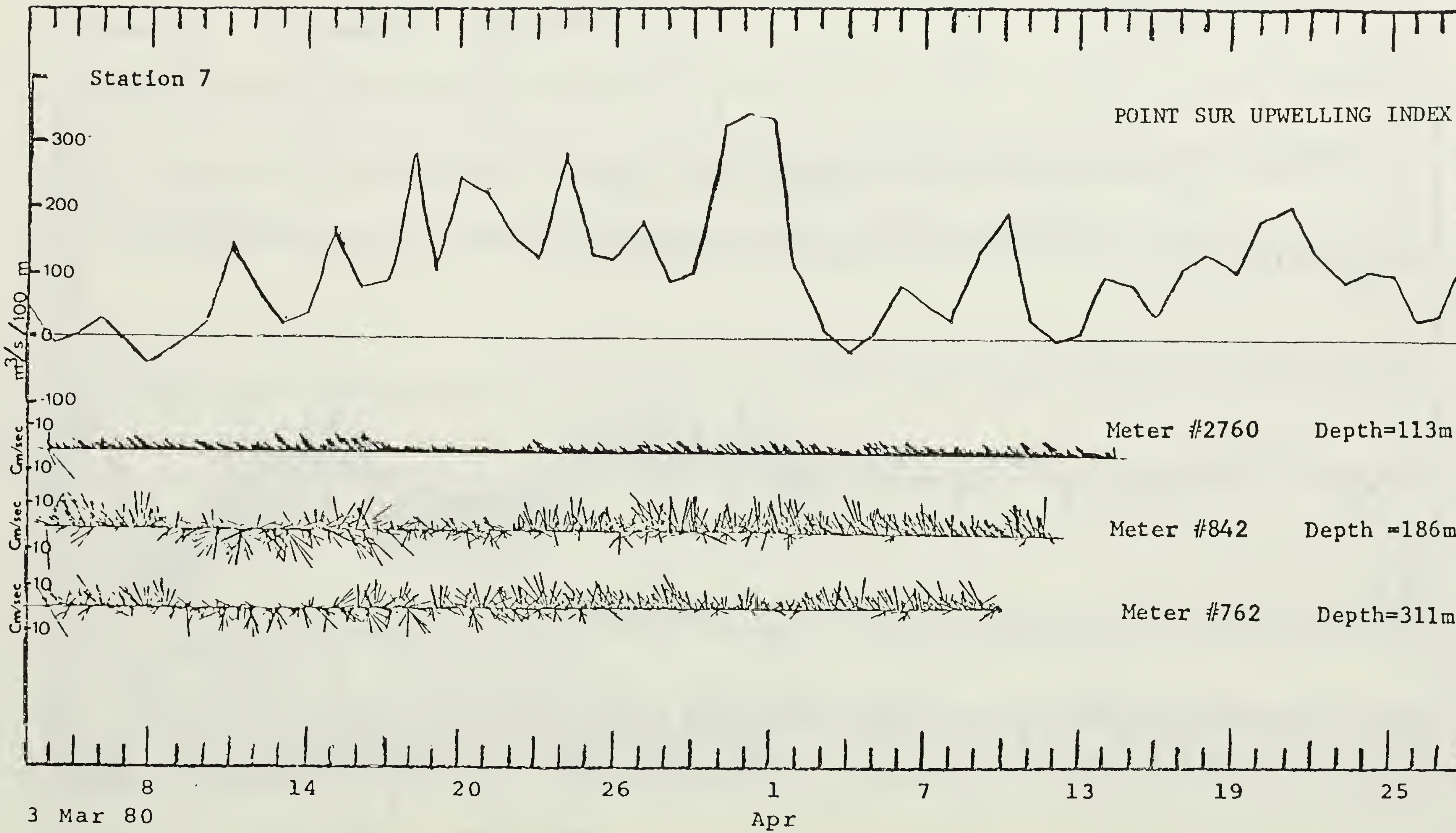


Figure 27. Point Sur Upwelling Index and stickplots of hourly current vectors for the current meters at Station 7 deployed on 3 March 1980.

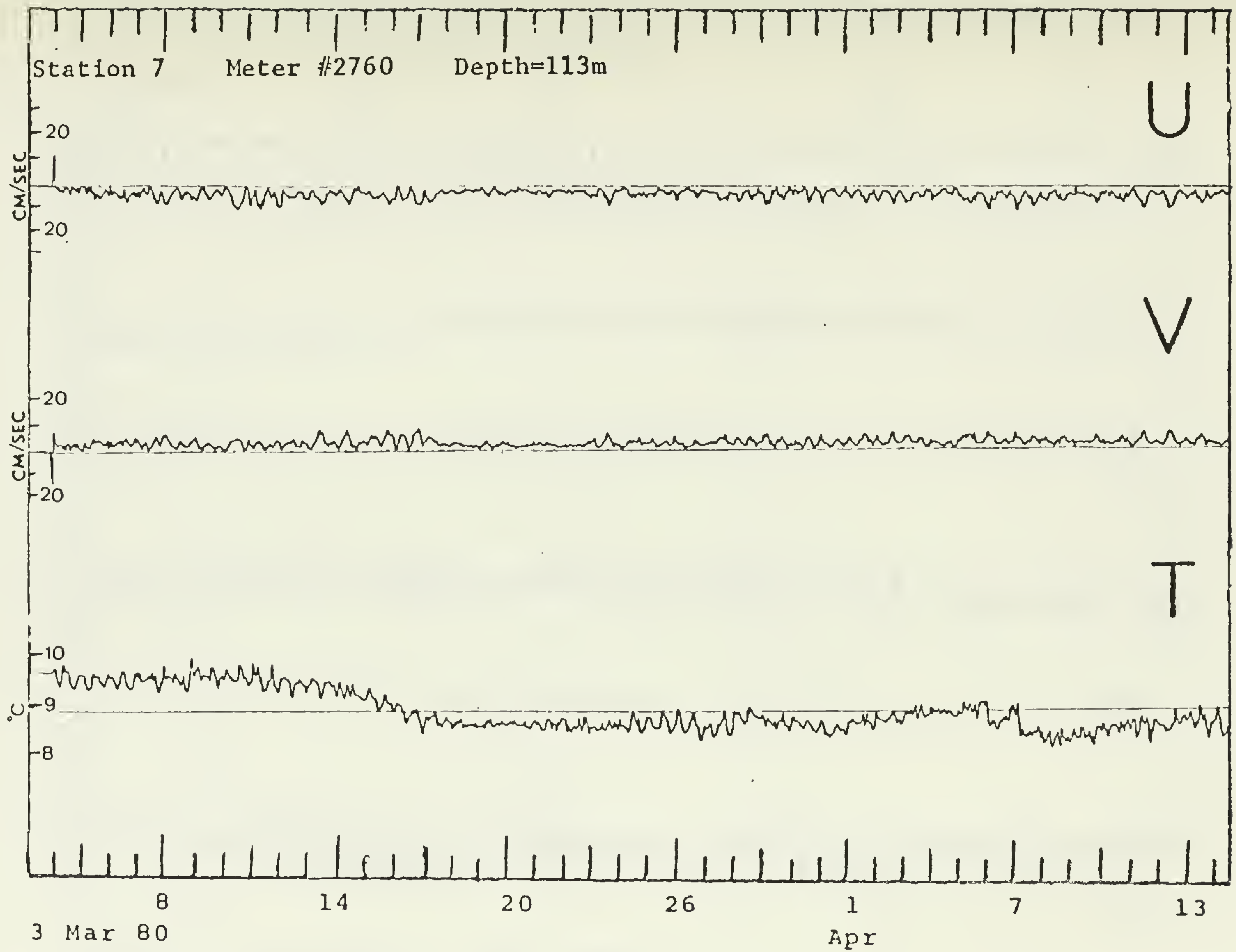


Figure 28. U component, V component, and temperature plots versus time for the current meter at 113 m depth at Station 7 deployed on 3 March 1980.

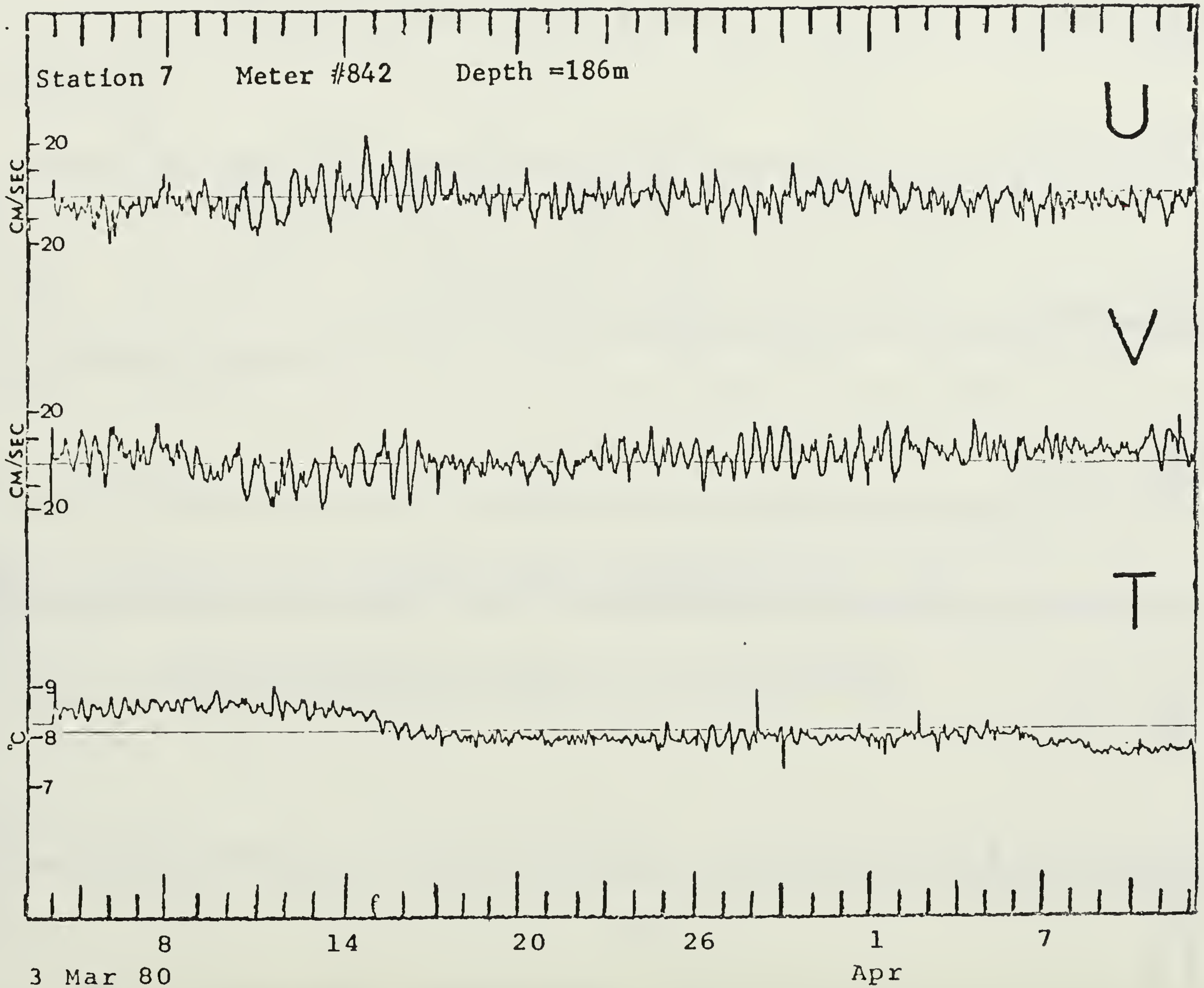


Figure 29. U component, V component, and temperature plots versus time for the current meters at 186 m depth at Station 7 deployed on 3 March 1980.

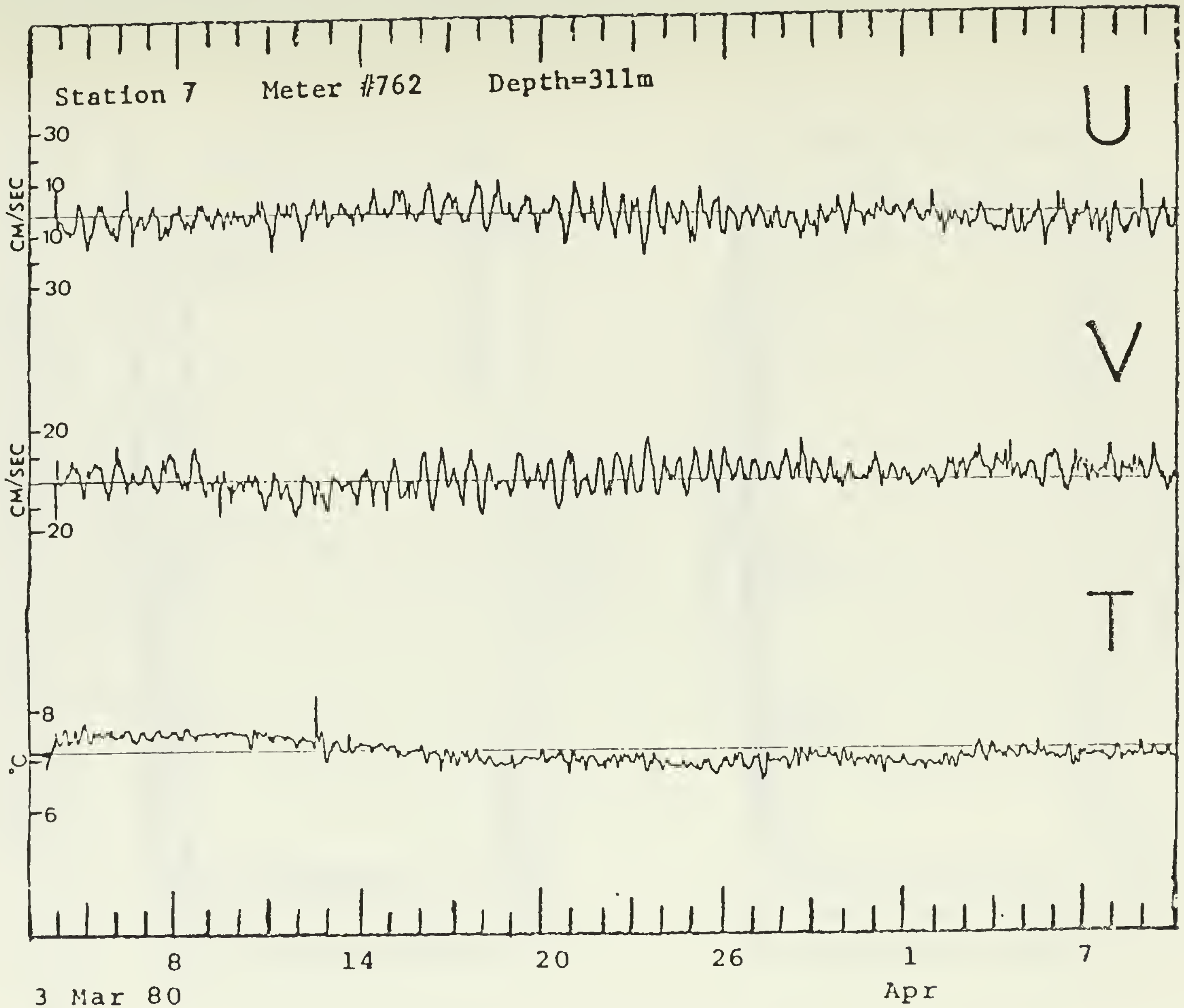
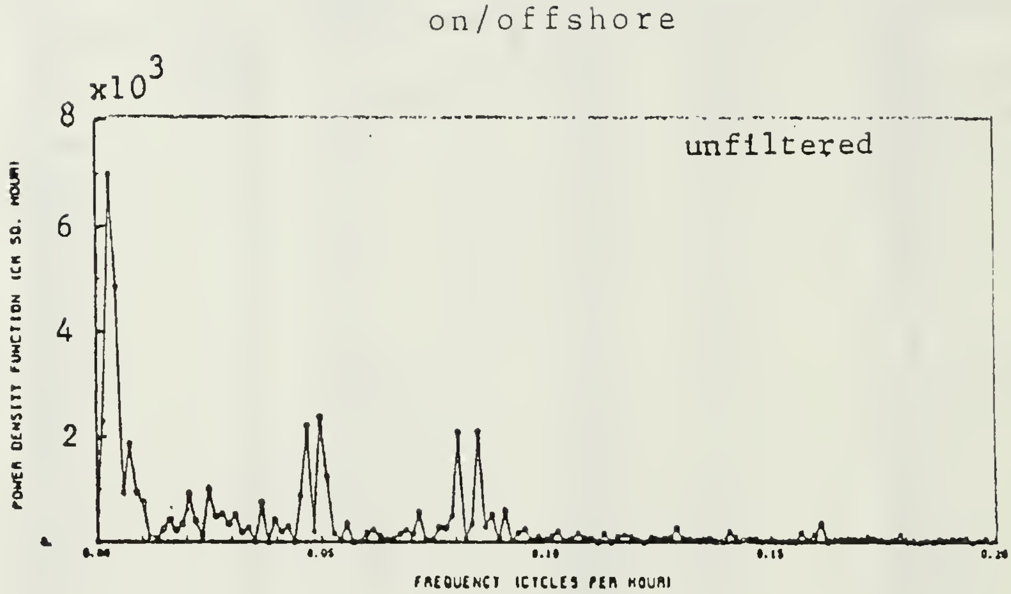


Figure 30. U component, V component, and temperature plots versus time for the current meter at 311 m depth at Station 7 deployed on 5 January 1979.

Station 7 Meter #762 Depth=152m 5 Jan 79



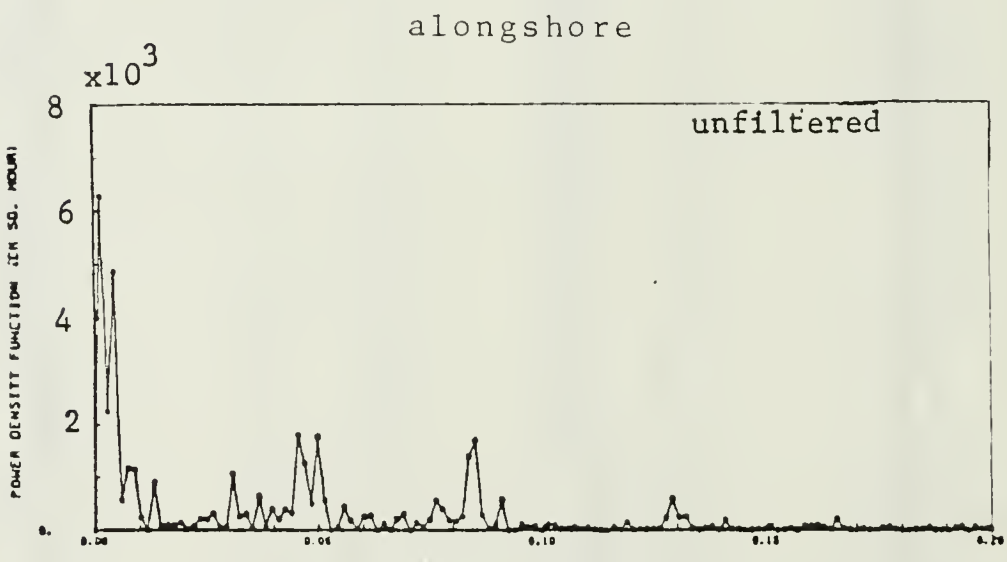


Figure 31. Energy density spectrum of current meter at 152 m depth at Station 7 deployed on 5 January 1979.

Station 7 Meter #842 Depth=223m 5 Jan 79

on/offshore

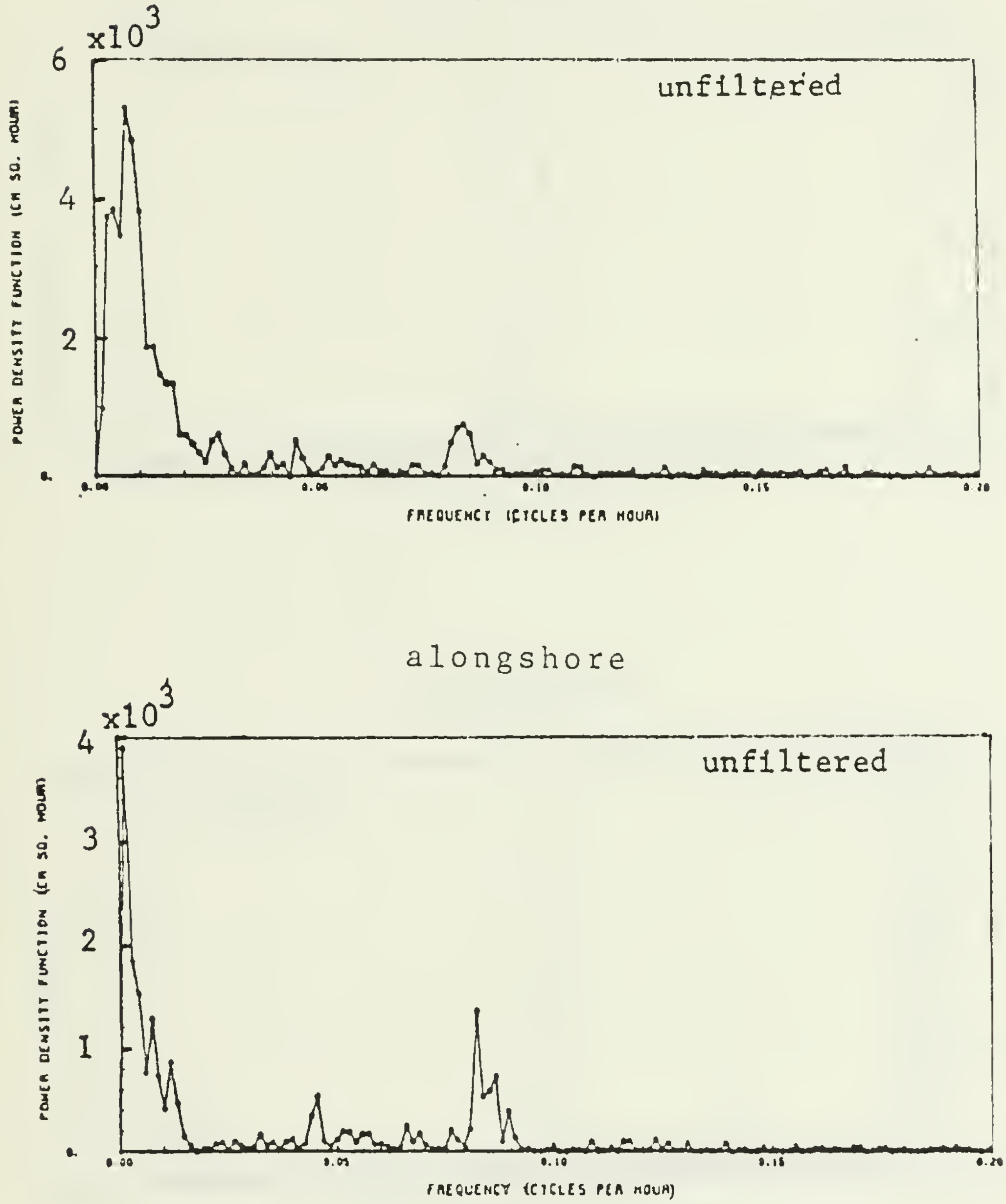


Figure 32. Energy density spectrum of current meter at 223 m depth at Station 7 deployed on 5 January 1979.

Station 2 Meter #1965 Depth=169m 23 Apr 79

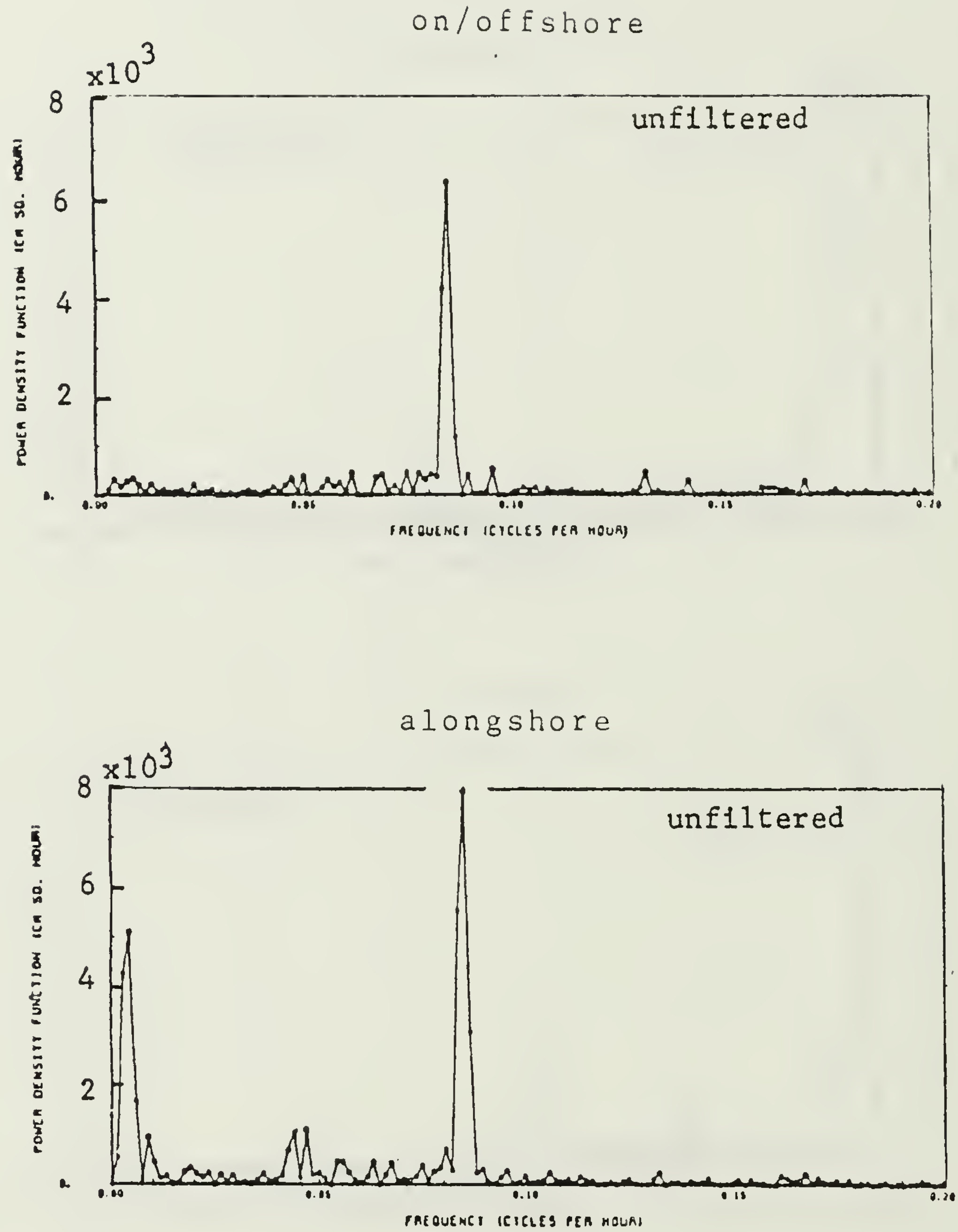
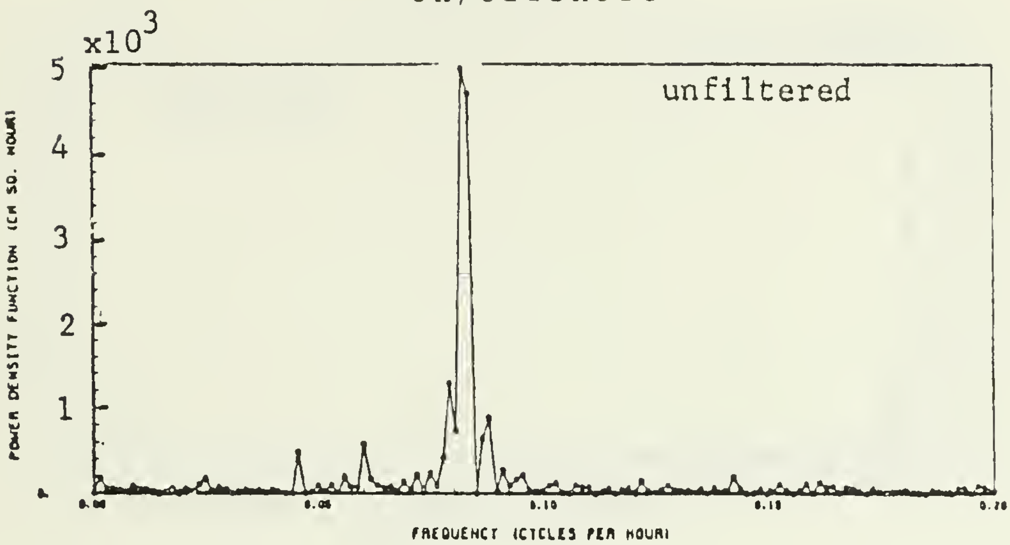


Figure 33. Energy density spectrum of current meter at 169 m depth at Station 2 deployed on 23 April 1979.

Station 2   Meter #1319   Depth=241m   23 Apr 79

on/offshore



alongshore

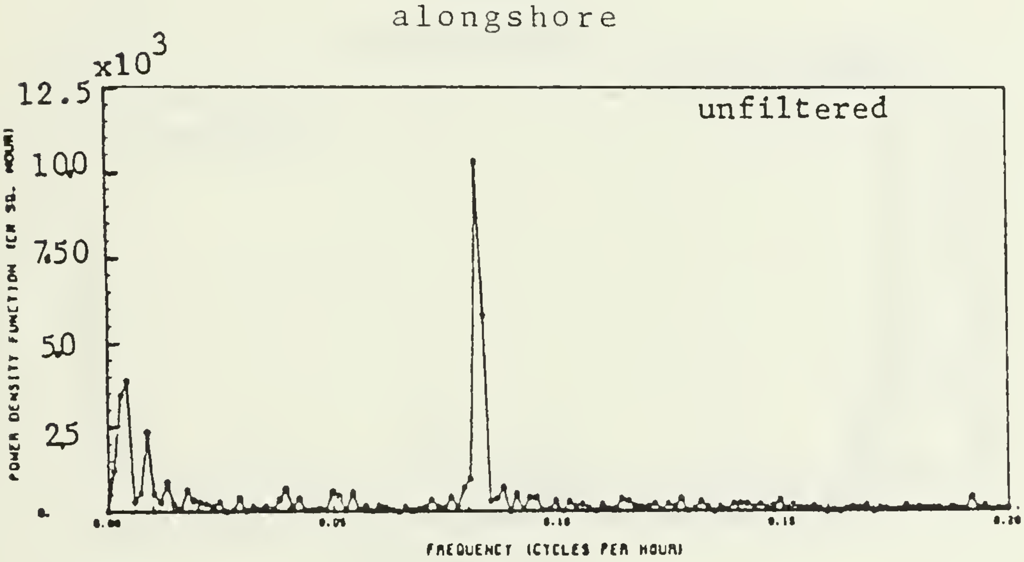
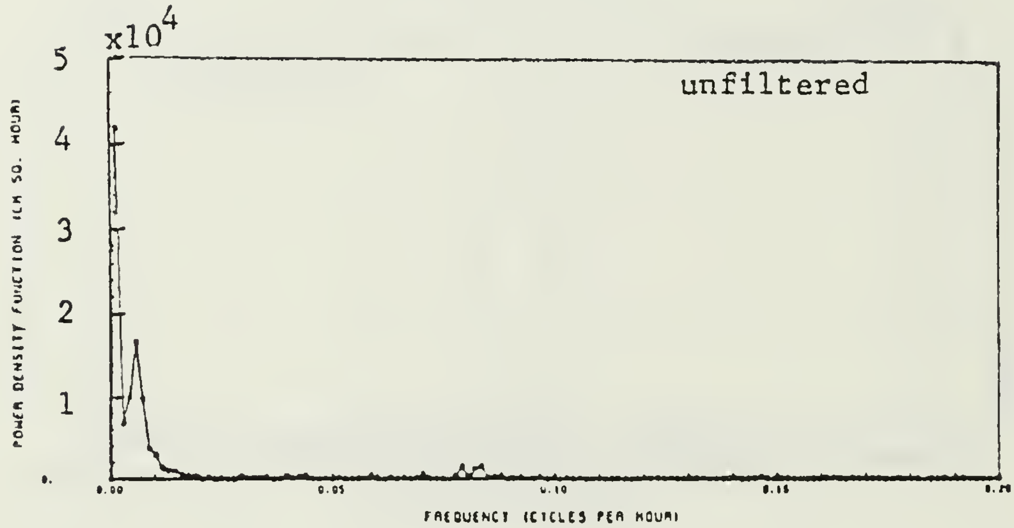


Figure 34. Energy density spectrum of current meter at 241 m depth at Station 2 deployed on 23 April 1979.

Station 7 Meter #2760 Depth=158m 7 Jul 79

on/offshore



alongshore

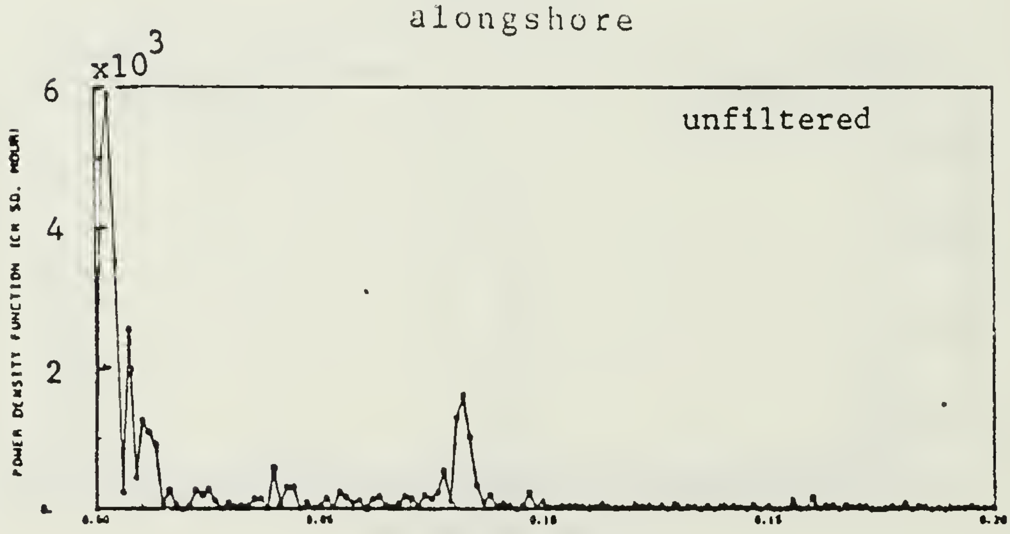


Figure 35. Energy density spectrum of current meter at 158 m depth at Station 7 deployed on 7 July 1979.

Station 7   Meter #842   Depth=231m   7 Jul 79

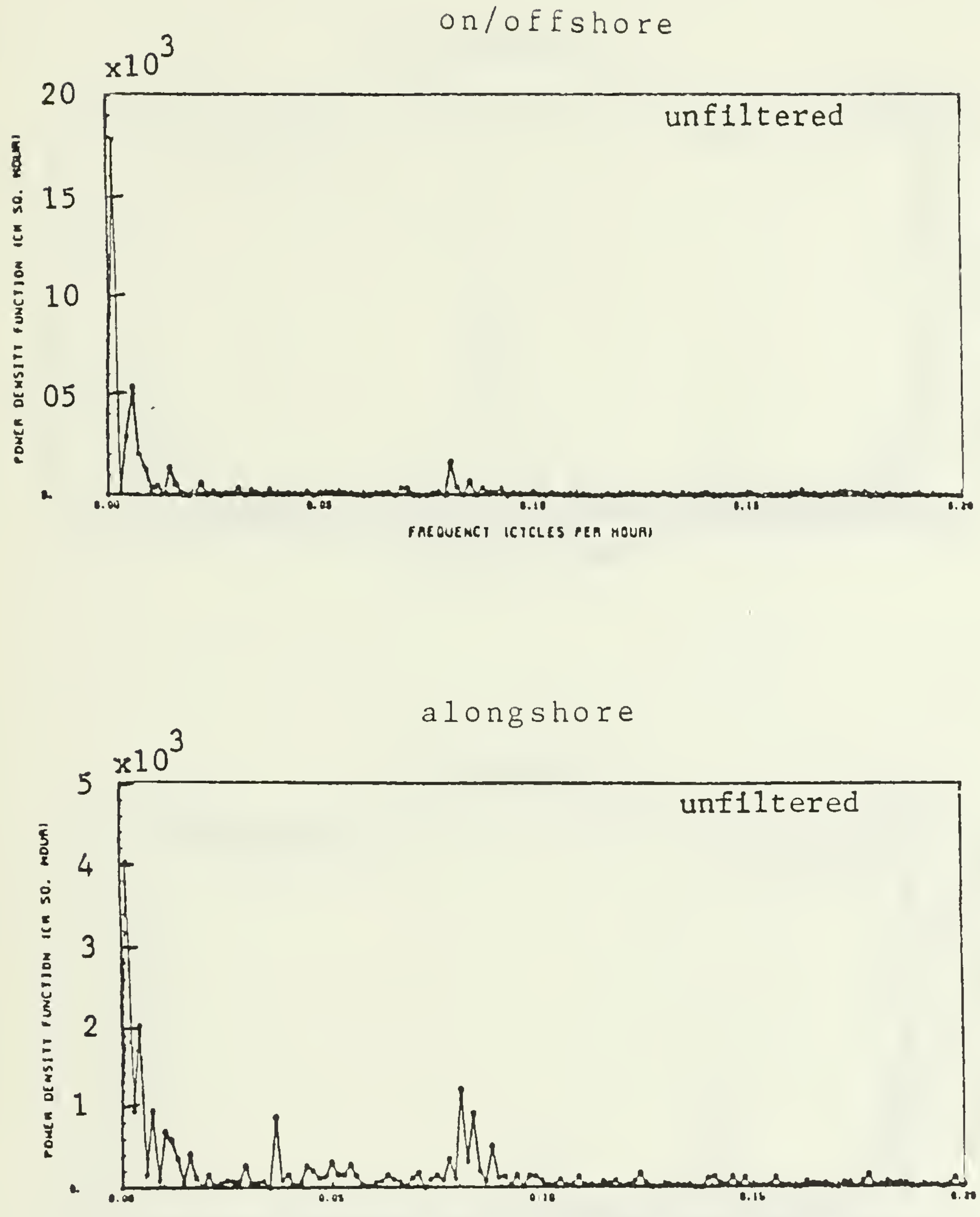
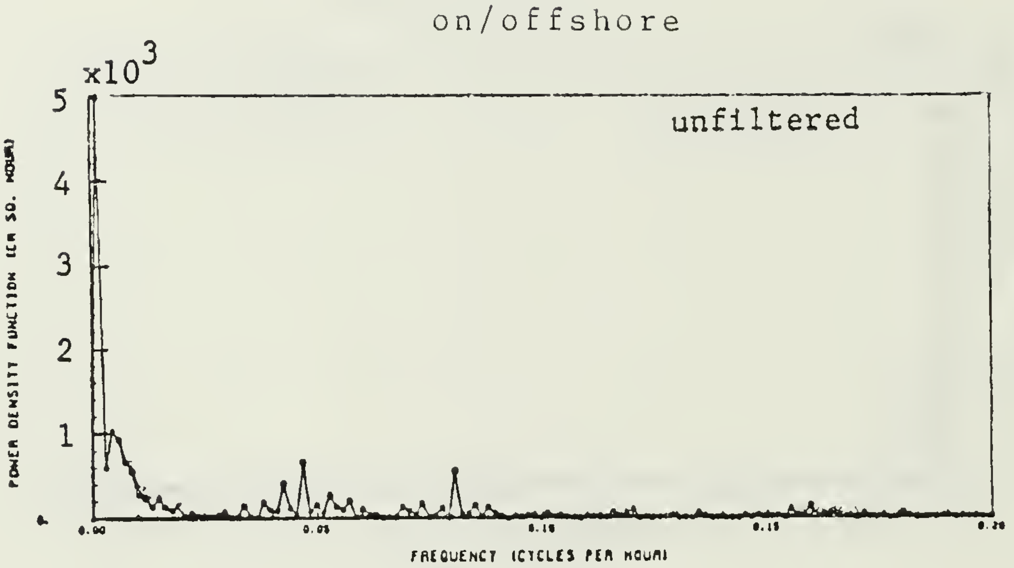


Figure 36. Energy density spectrum of current meter at 231 m depth at Station 7 deployed on 7 July 1979.

Station 7   Meter #762   Depth=356m   7 Jul 79



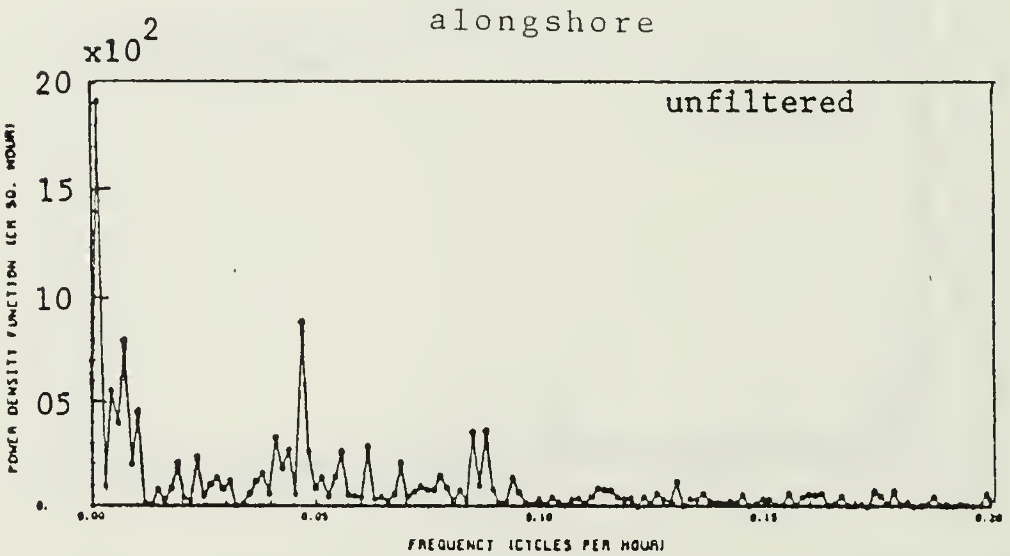
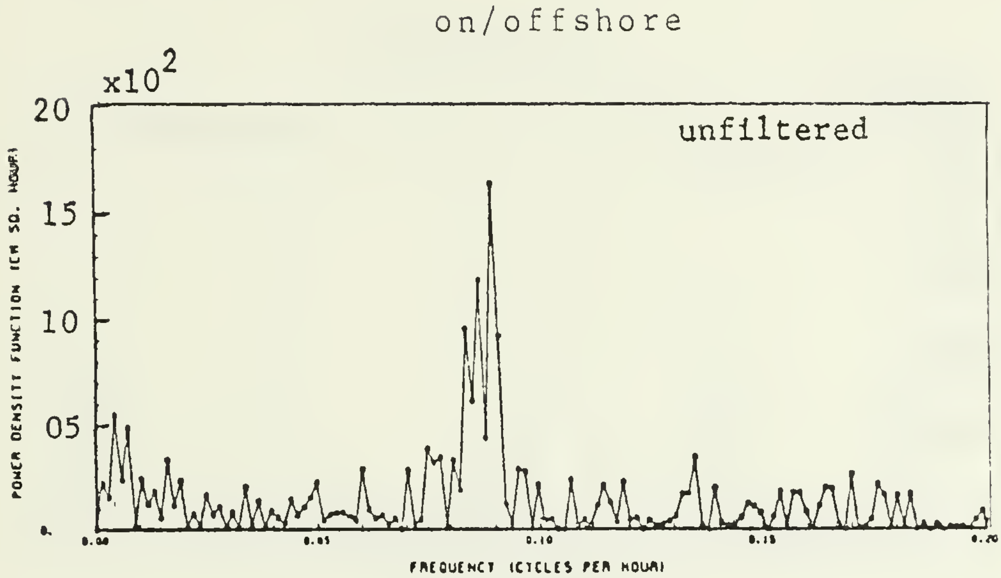


Figure 37. Energy density spectrum of current meter at 356 m depth at Station 7 deployed on 7 July 1979.

Station 2 Meter #1965 Depth=165m 21 Jul 79



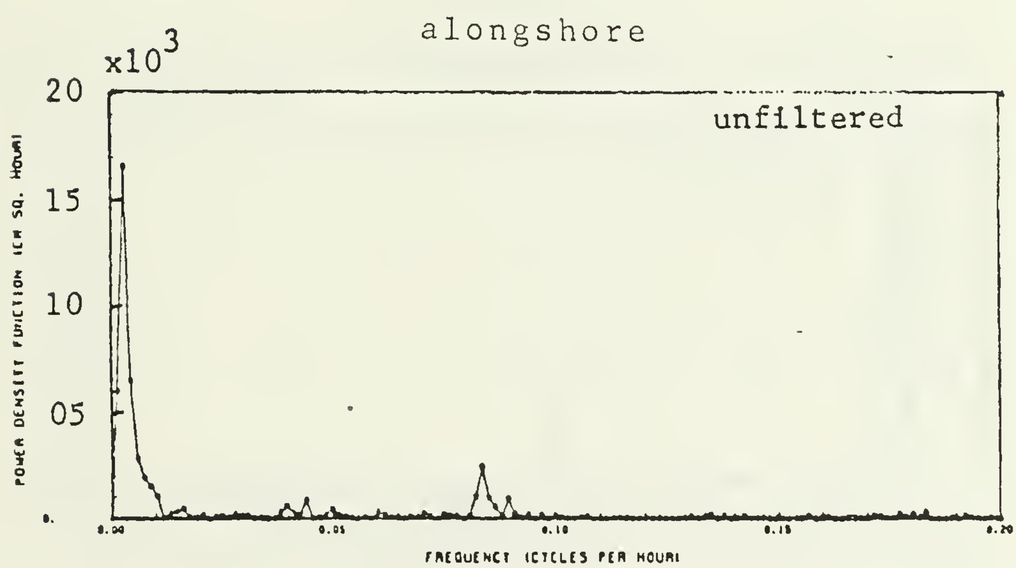
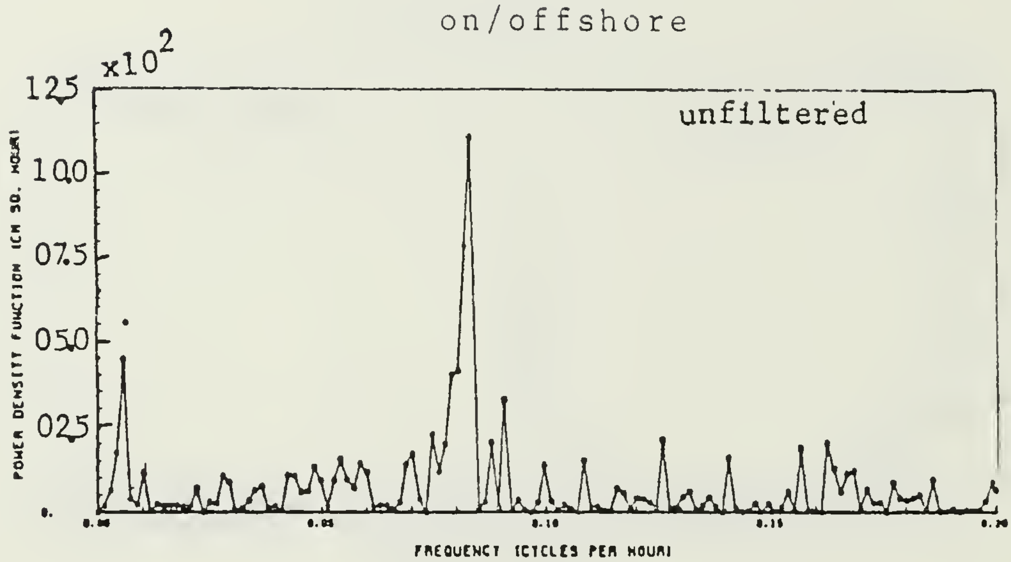


Figure 38. Energy density spectrum of current meter at 165 m depth at Station 2 deployed on 21 July 1979.

Station 2 Meter #1319 Depth=237m 21 Jul 79

on/offshore



alongshore

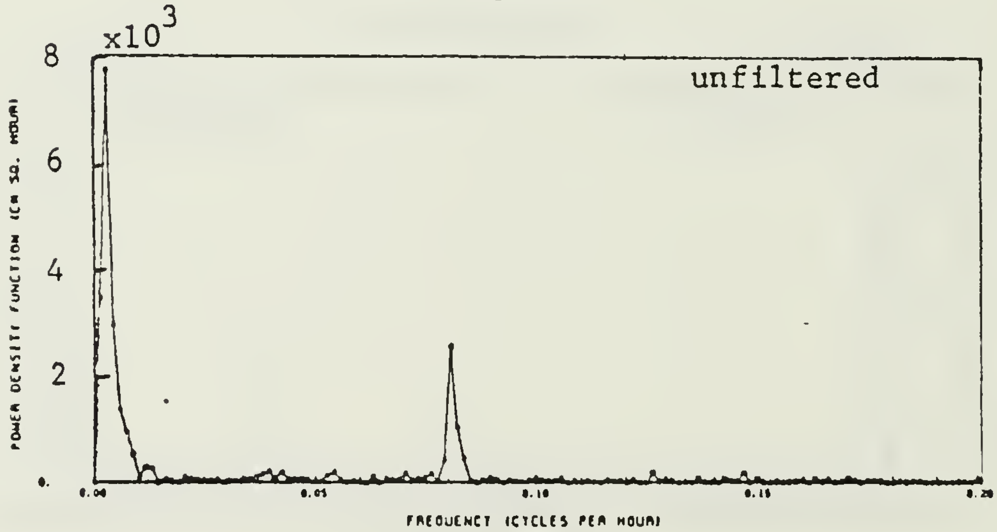
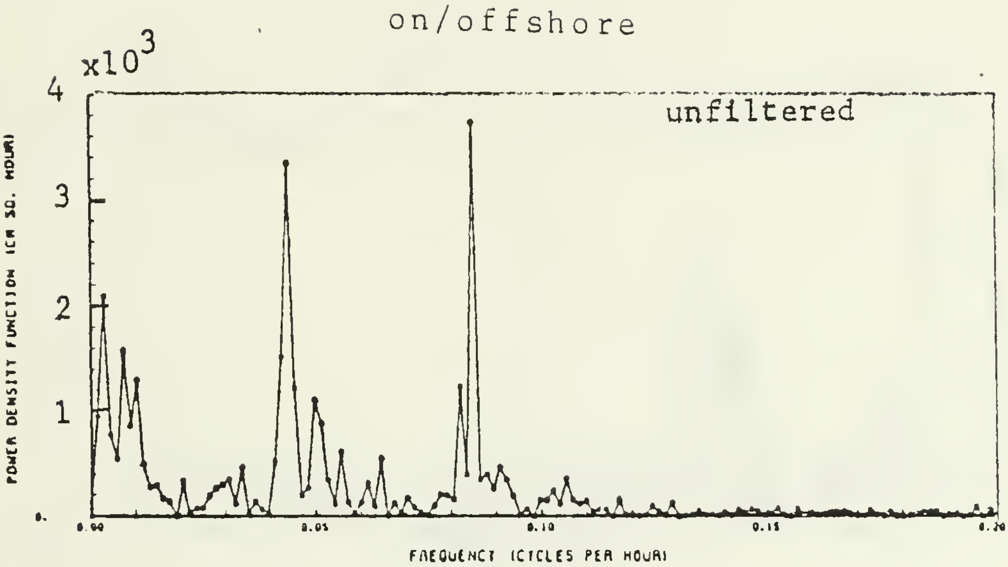


Figure 39. Energy density spectrum of current meter at 237 m depth at Station 2 deployed on 21 July 1979.

Station 7 Meter #2760 Depth=127m 7 Oct 79

on/offshore



alongshore

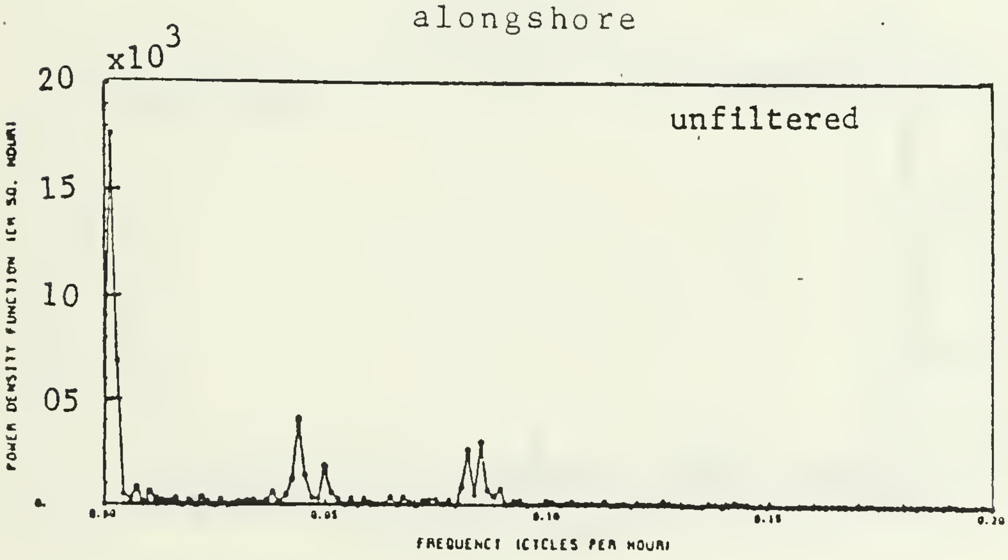
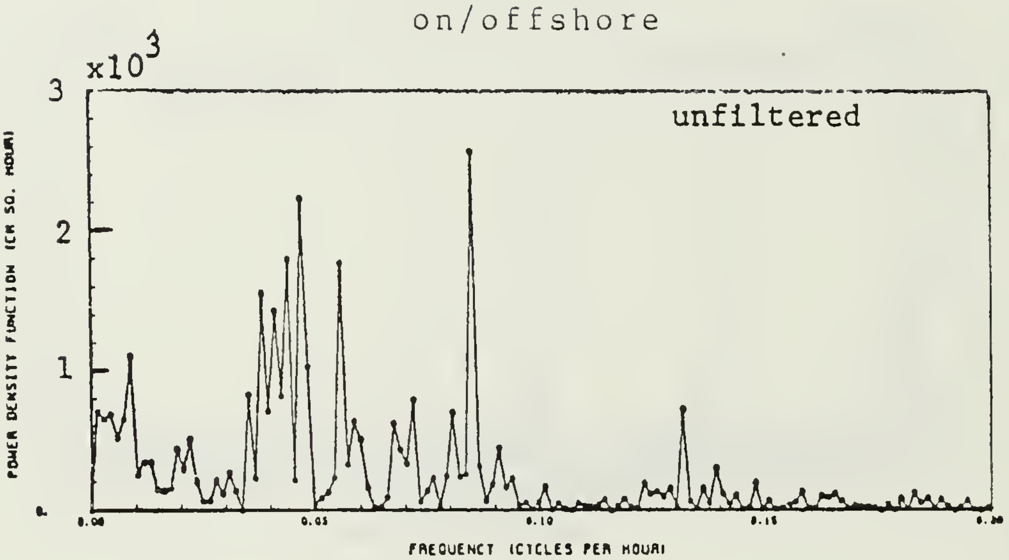


Figure 40. Energy denisty spectrum of current meter at 127 m depth at Station 7 deployed on 7 October 1979.

Station 7 Meter #842 Depth=200m 7 Oct 79



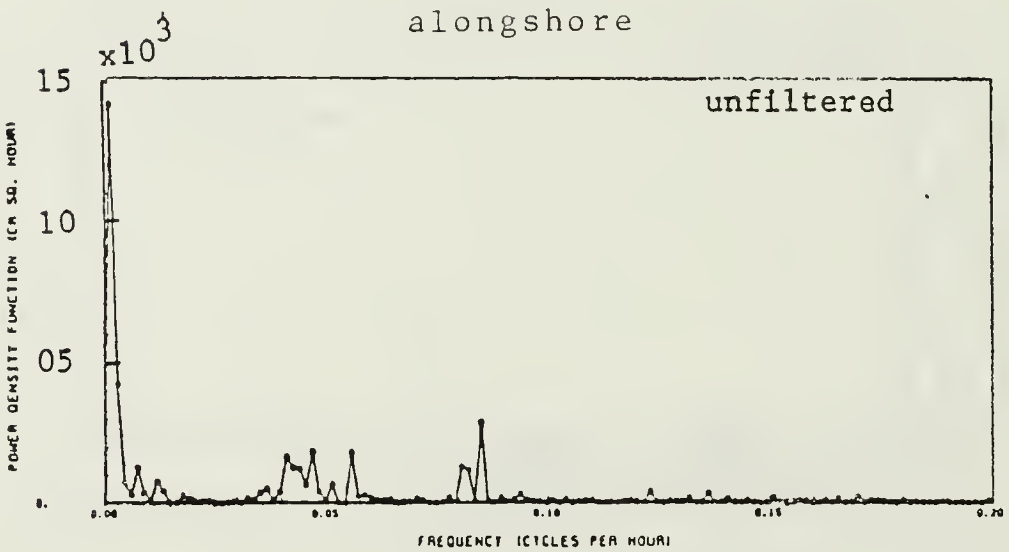


Figure 41. Energy density spectrum of current meter at 200 m depth at Station 7 deployed on 7 October 1979.

Station 2 Meter #1965 Depth=194m 24 Nov 79

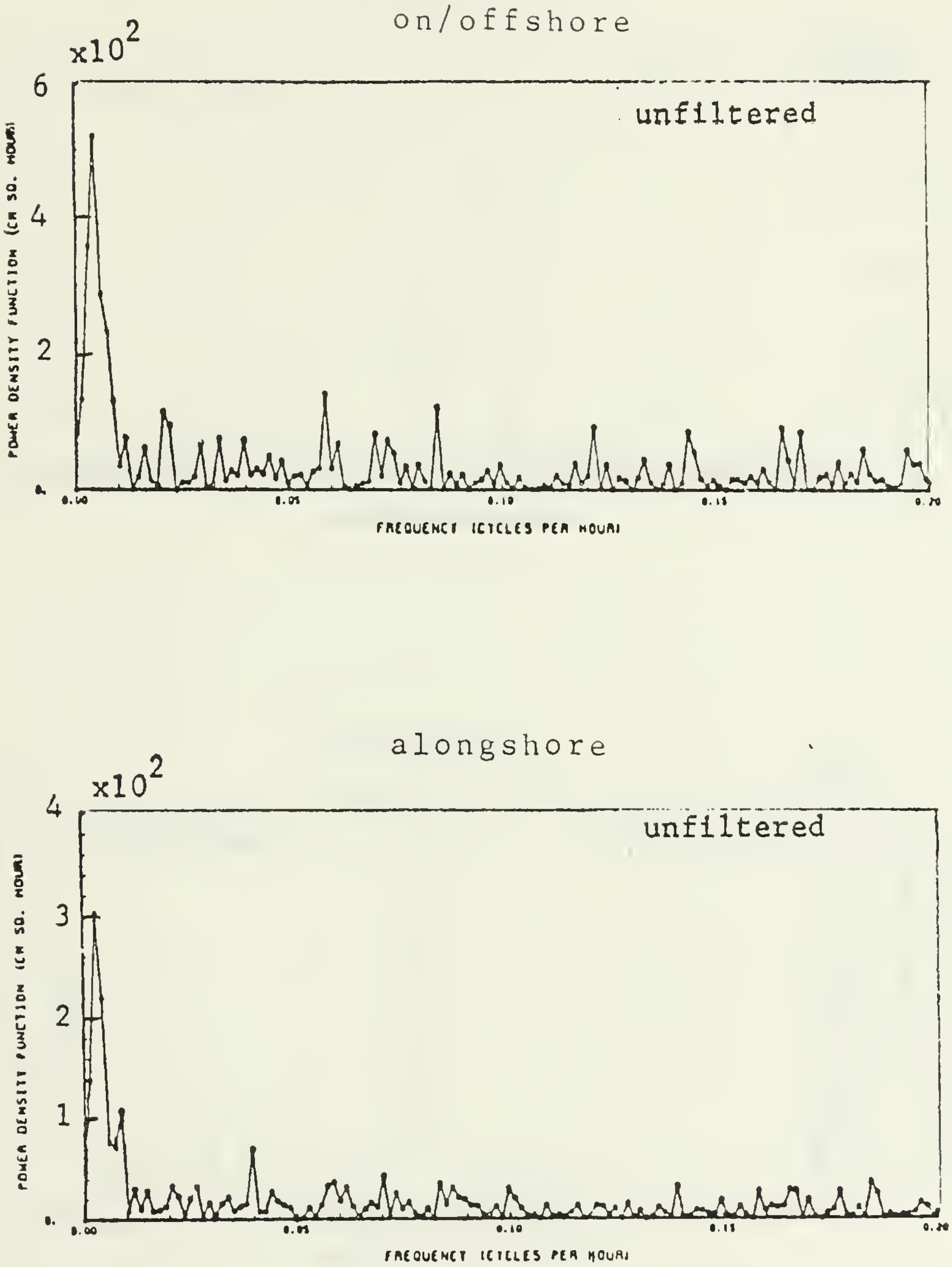
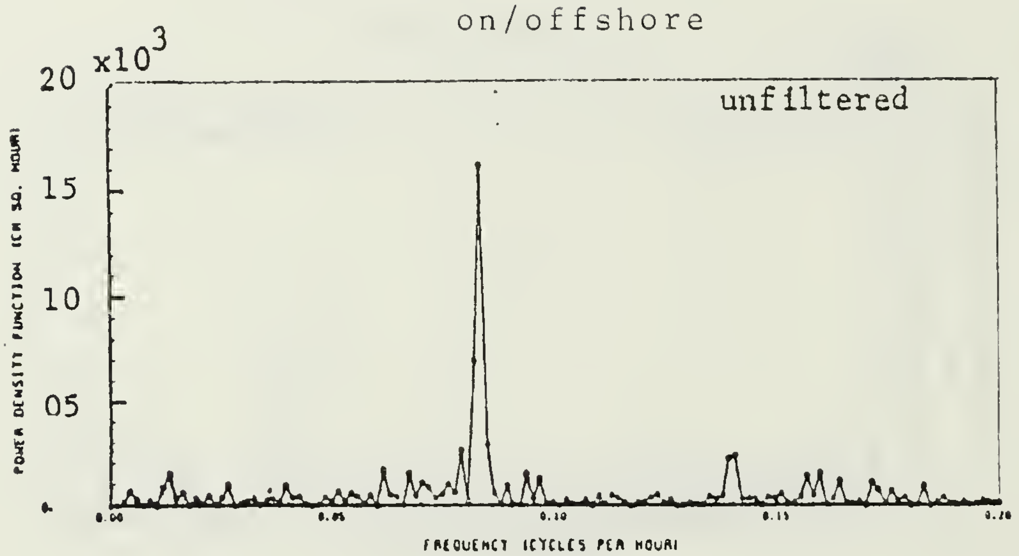


Figure 42. Energy density spectrum of current meter at 194 m depth at Station 2 deployed on 24 November 1979.

Station 2   Meter #1319   Depth=266m   24 Nov 79

on/offshore



alongshore

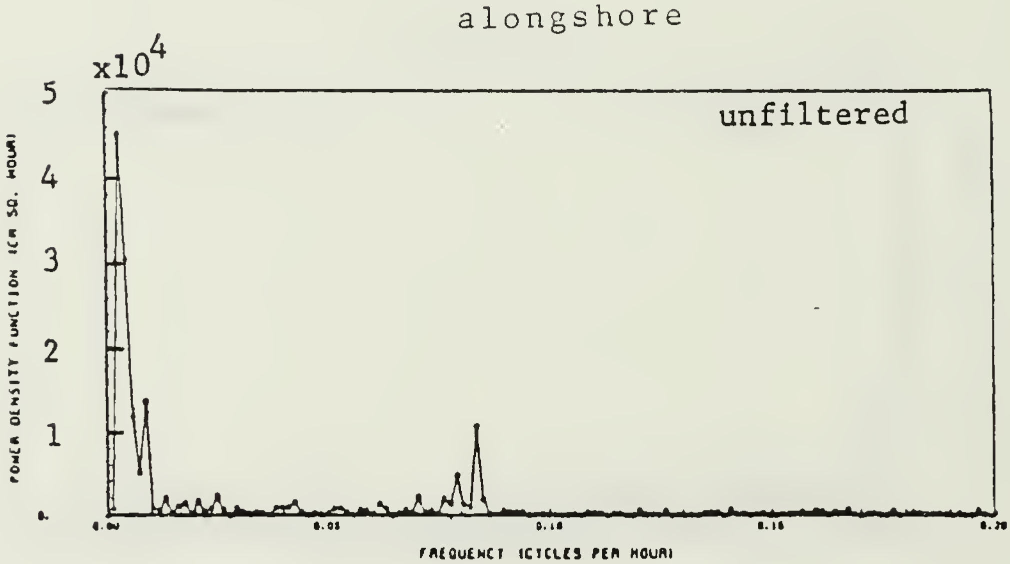
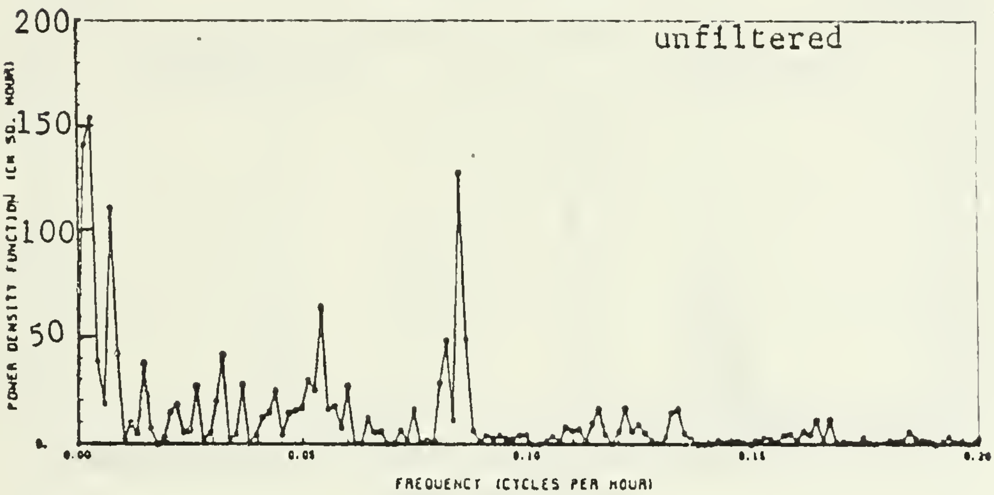


Figure 43. Energy density spectrum of current meter at 266 m depth at Station 2 deployed on 24 November 1979.

Station 7 Meter #2760 Depth=113m 3 Mar 80

on/offshore



alongshore

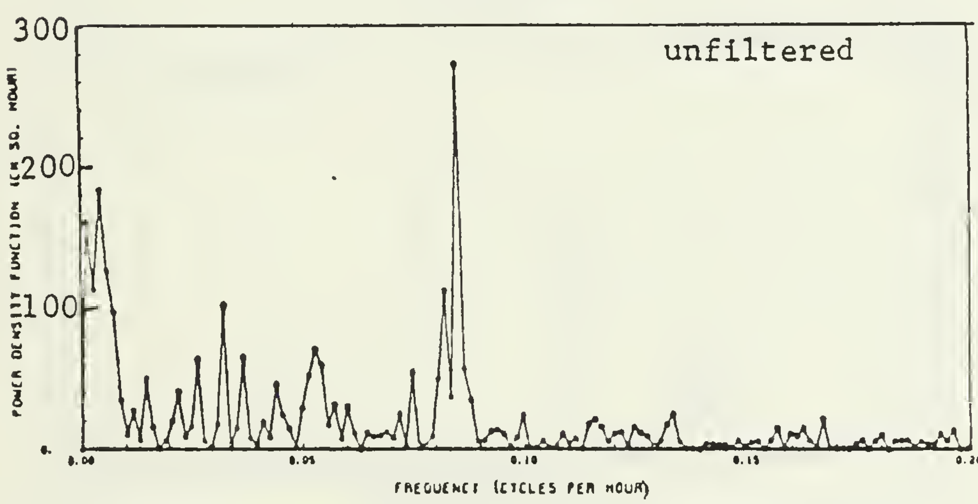


Figure 44. Energy density spectrum of current meter at 113 m depth at Station 7 deployed on 3 March 1980.

Station 7 Meter #842 Depth =186m 3 Mar 80

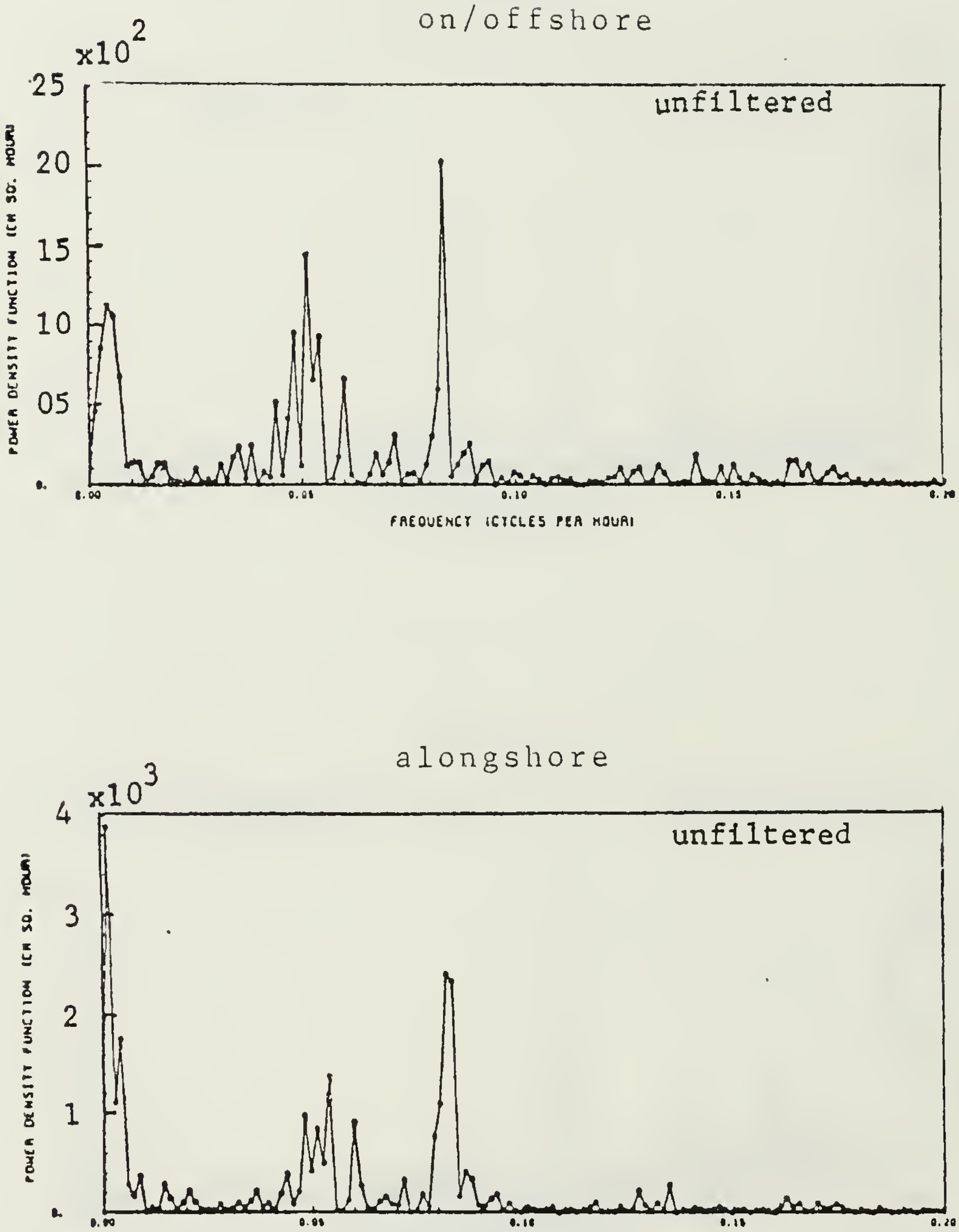


Figure 45. Energy density spectrum of current meter at 186 m depth at Station 7 deployed on 3 March 1980.

Station 7   Meter #762   Depth=311m   3 Mar 80

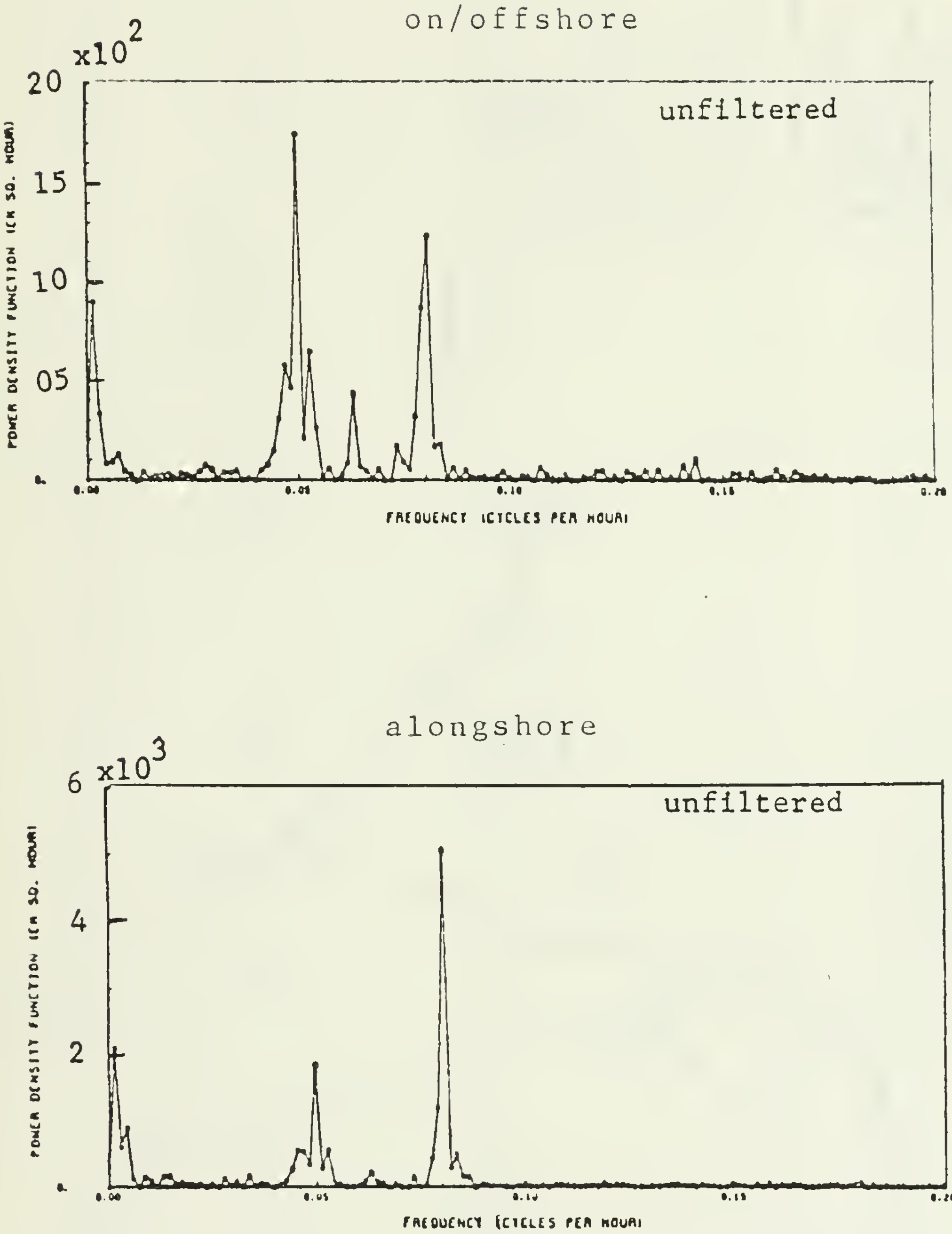


Figure 46. Energy density spectrum of current meter at 311 m depth at Station 7 deployed on 3 March 1980.

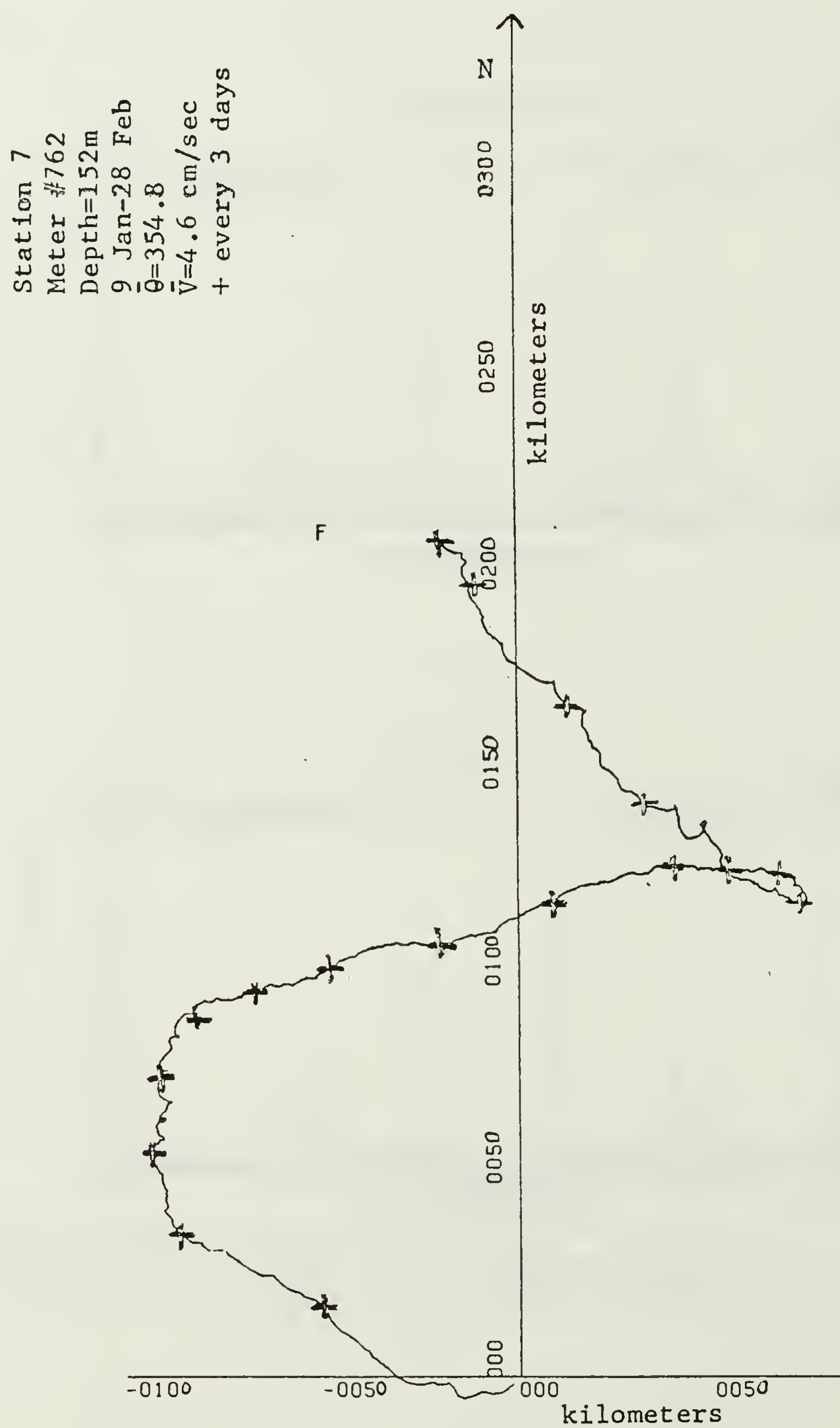


Figure 47. Progressive vector diagram for the current meter at 127 m depth at Station 7 from 9 January to 28 February 1979.

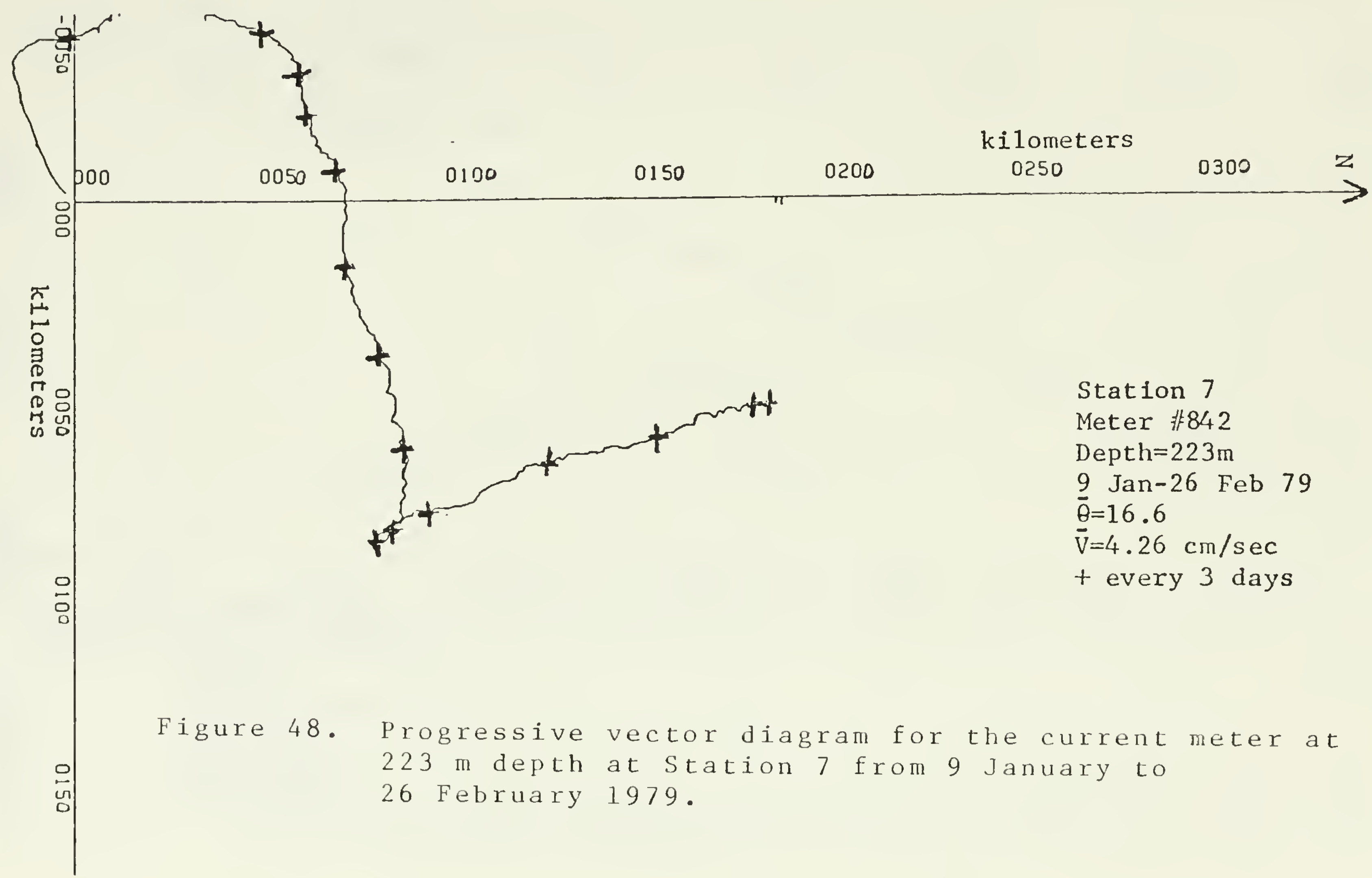


Figure 48. Progressive vector diagram for the current meter at 223 m depth at Station 7 from 9 January to 26 February 1979.

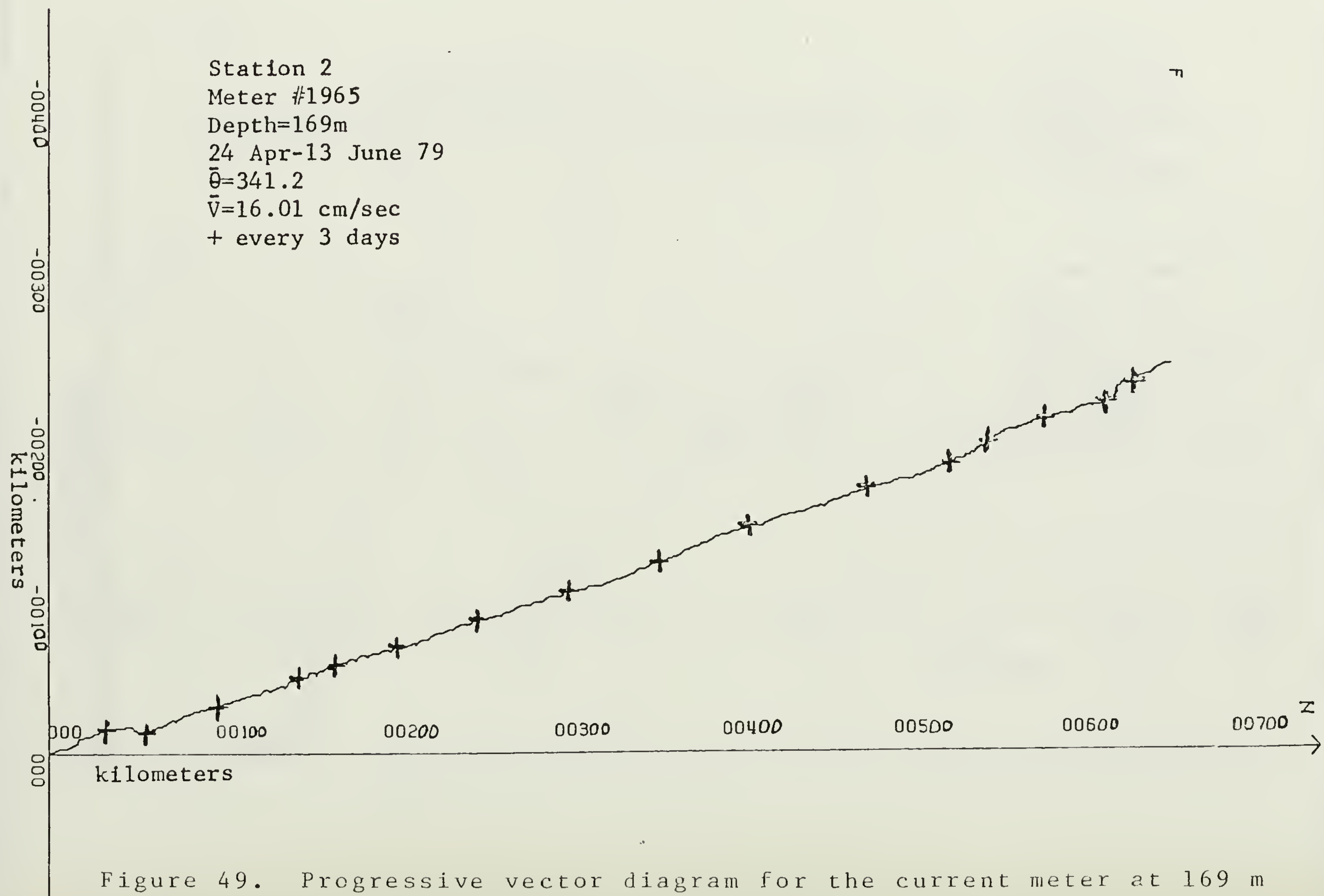


Figure 49. Progressive vector diagram for the current meter at 169 m depth at Station 2 from 24 April to 13 June 1979.

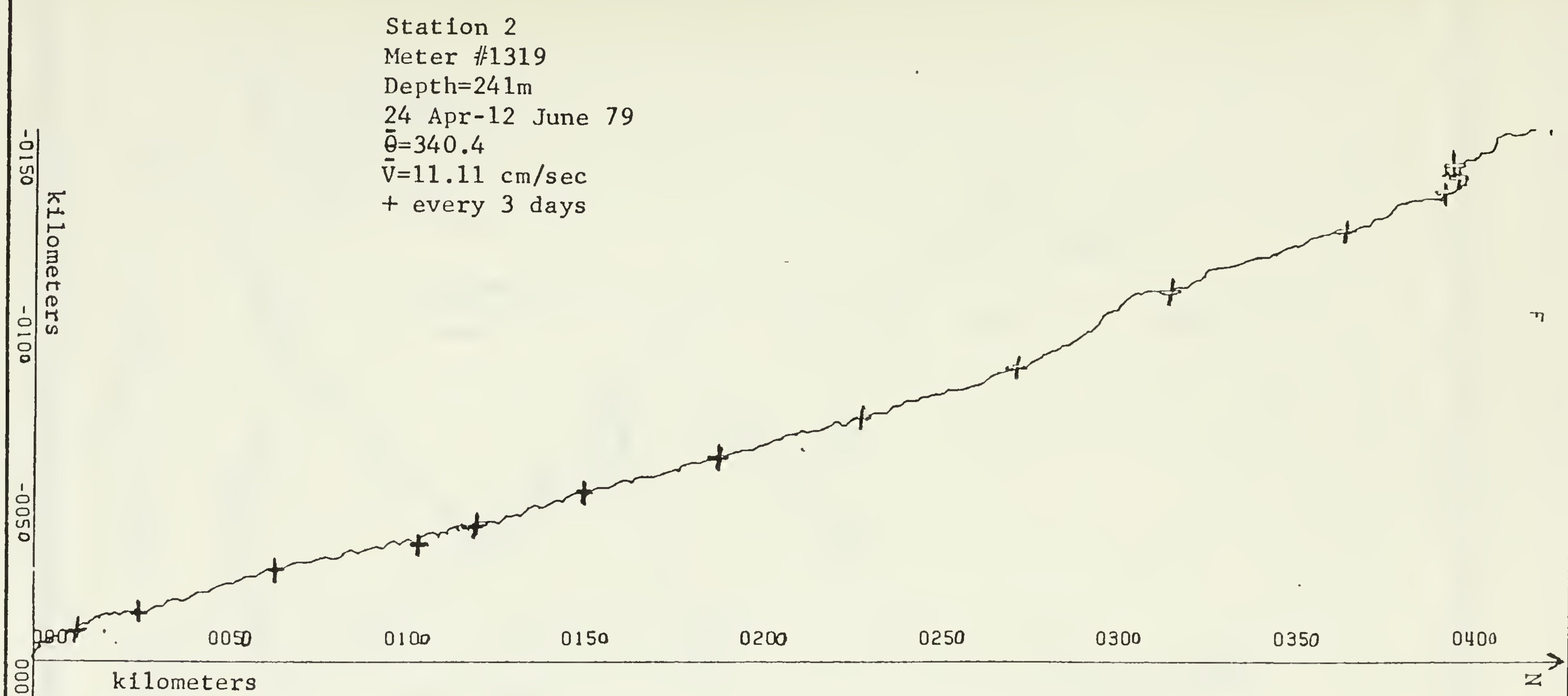


Figure 50. Progressive vector diagram for the current meter at 241 m depth at Station 2 from 24 April 12 June 1979.

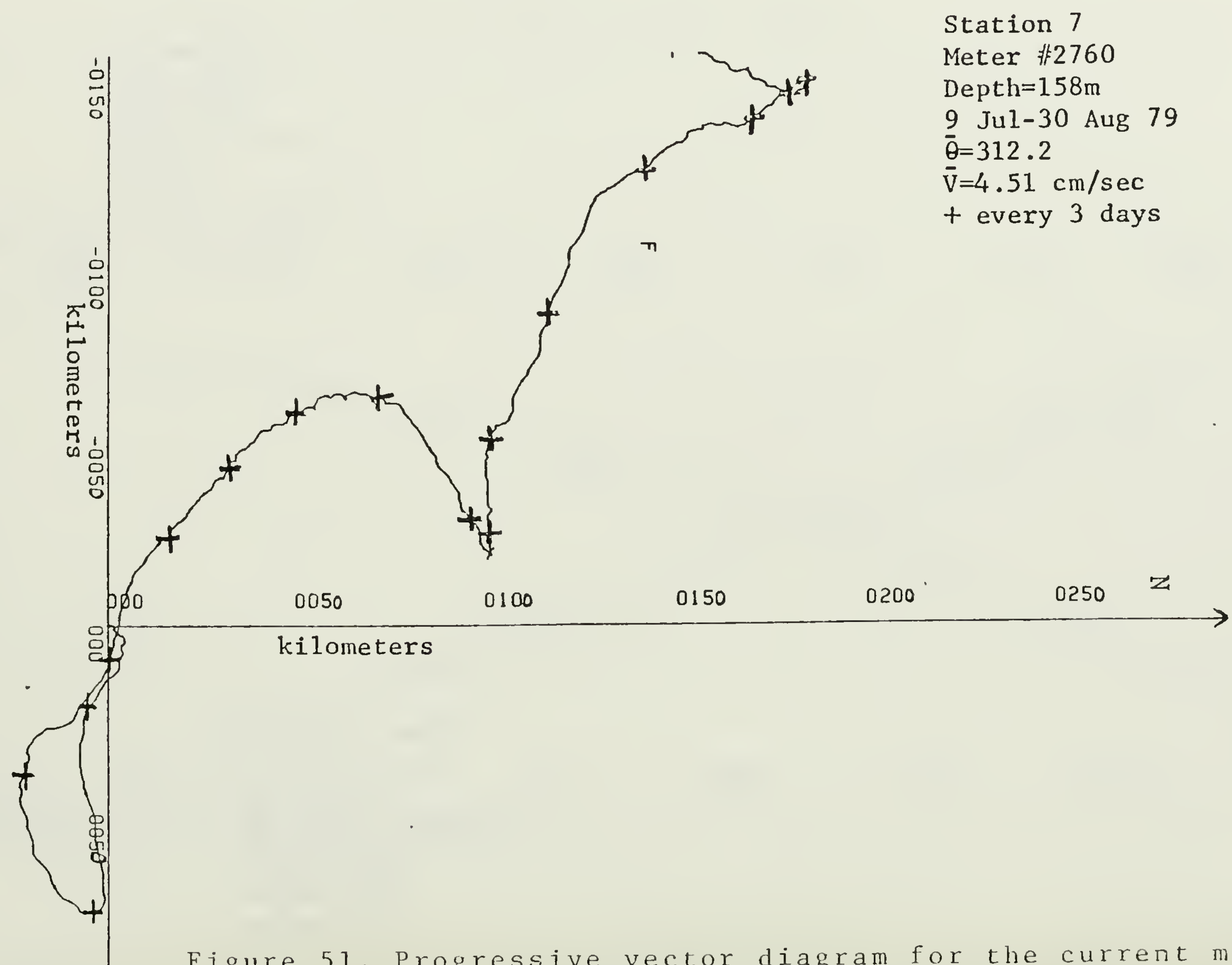


Figure 51. Progressive vector diagram for the current meter at 158 m depth at Station 7 from 9 July to 30 August 1979.

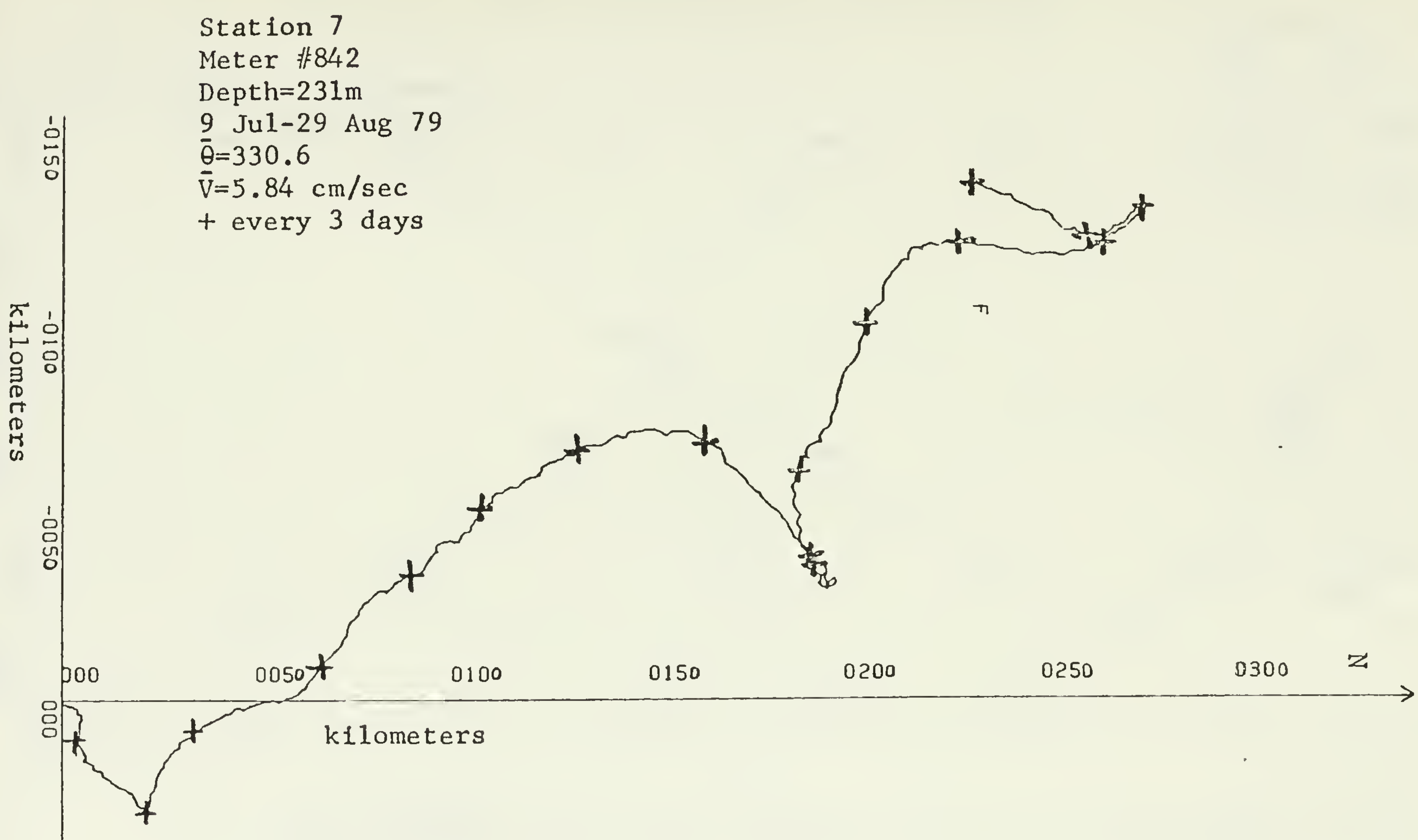


Figure 52. Progressive vector diagram for the current meter at 231 m depth at Station 7 from 9 July to 29 August 1979.

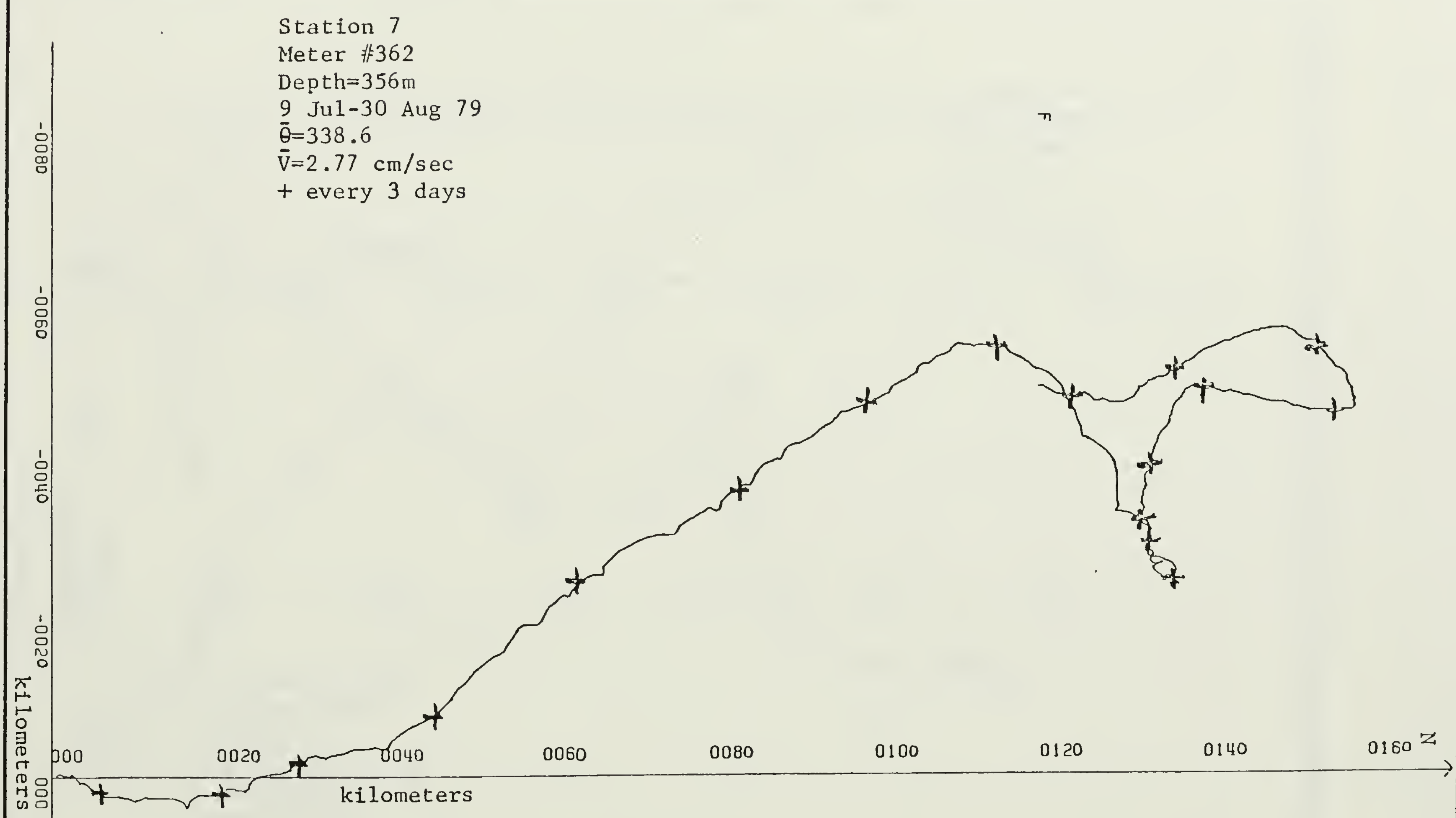


Figure 53. Progressive vector diagram for the current meter at 356 m depth at Station 7 from 9 July to 30 August 1979.

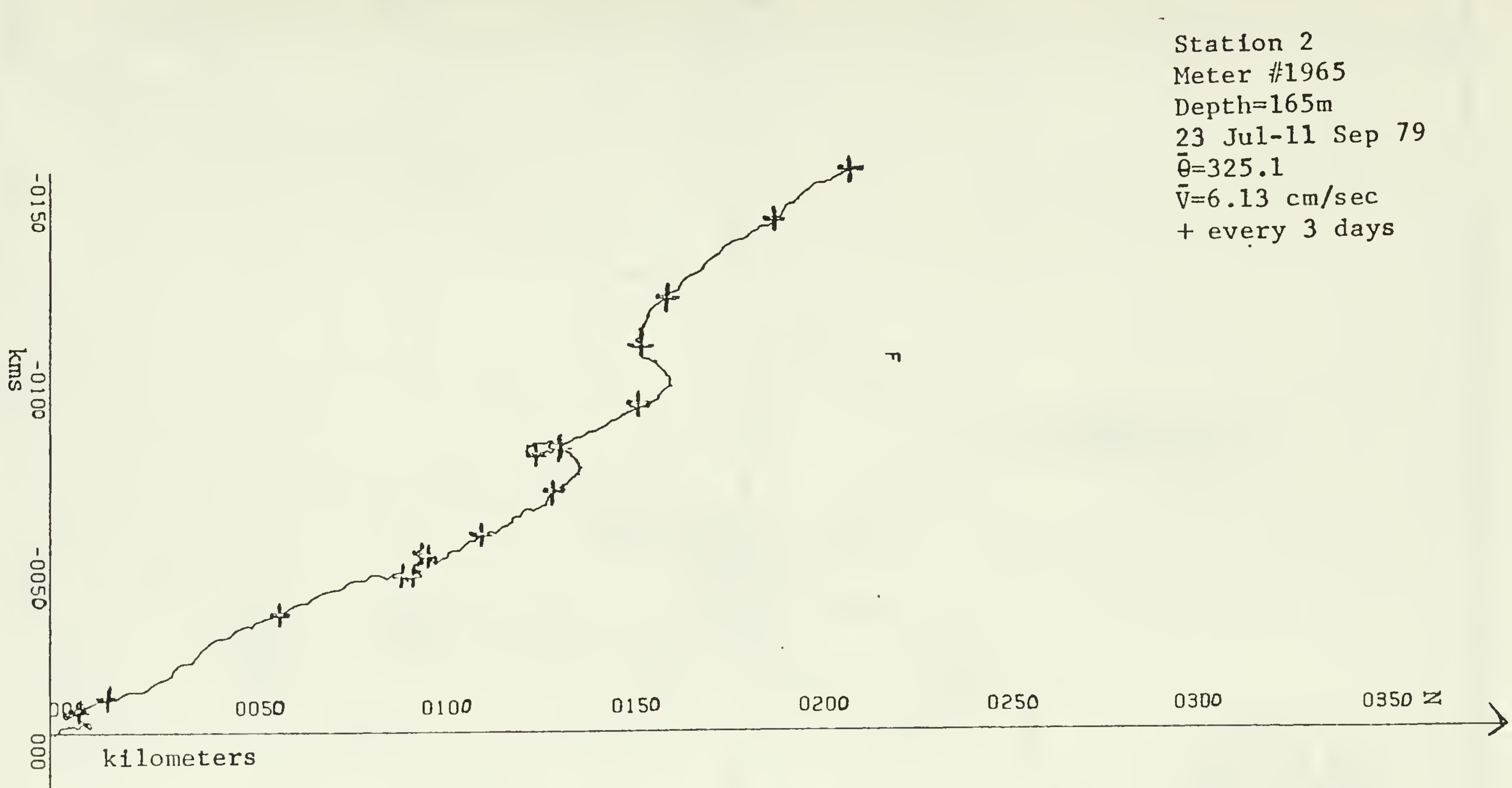


Figure 54. Progressive vector diagram for the current meter at 165 m depth at Station 2 from 23 July to 11 September 1979.

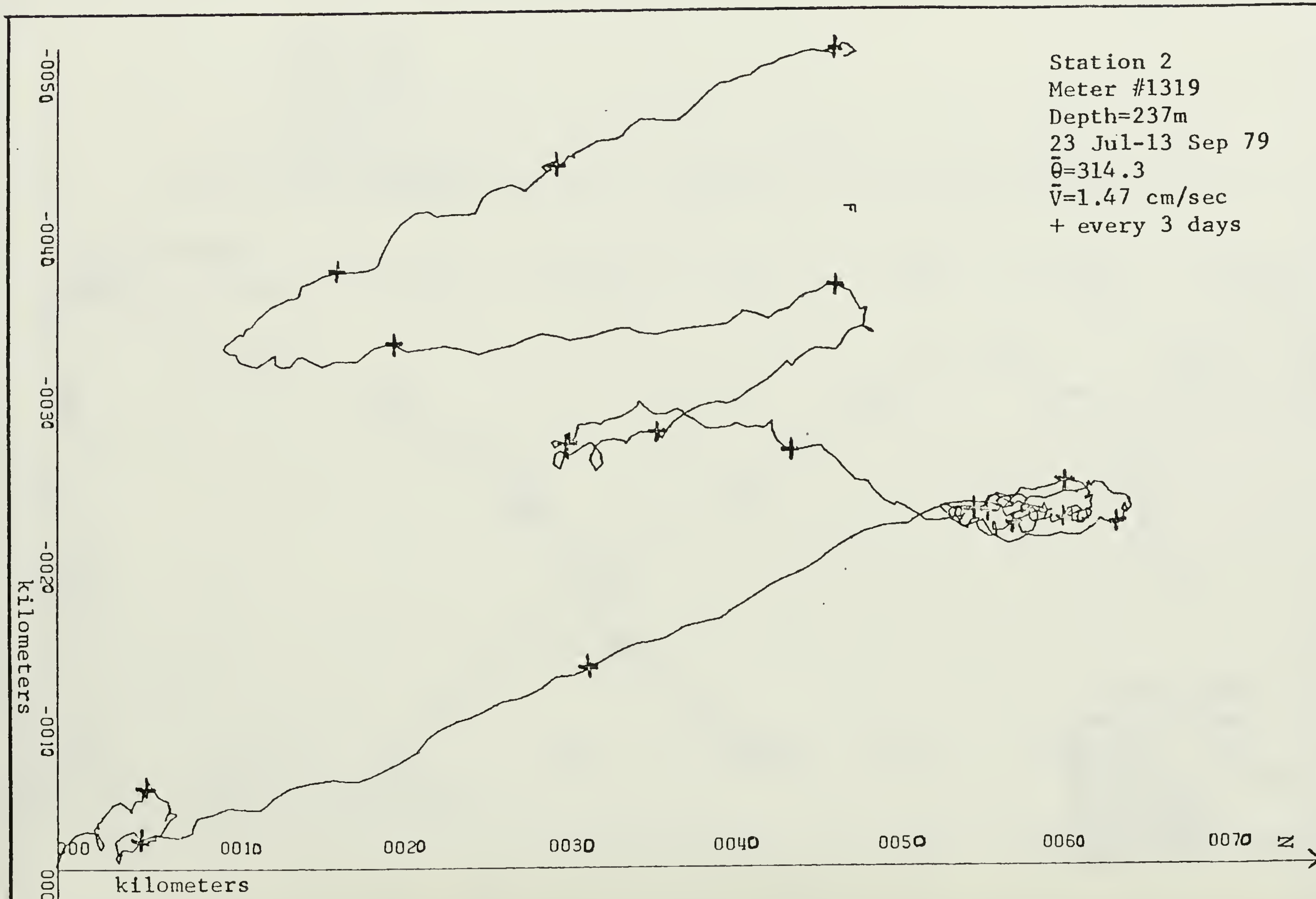


Figure 55. Progressive vector diagram for the current meter at 237 m depth at Station 2 from 23 July to 13 September 1979.

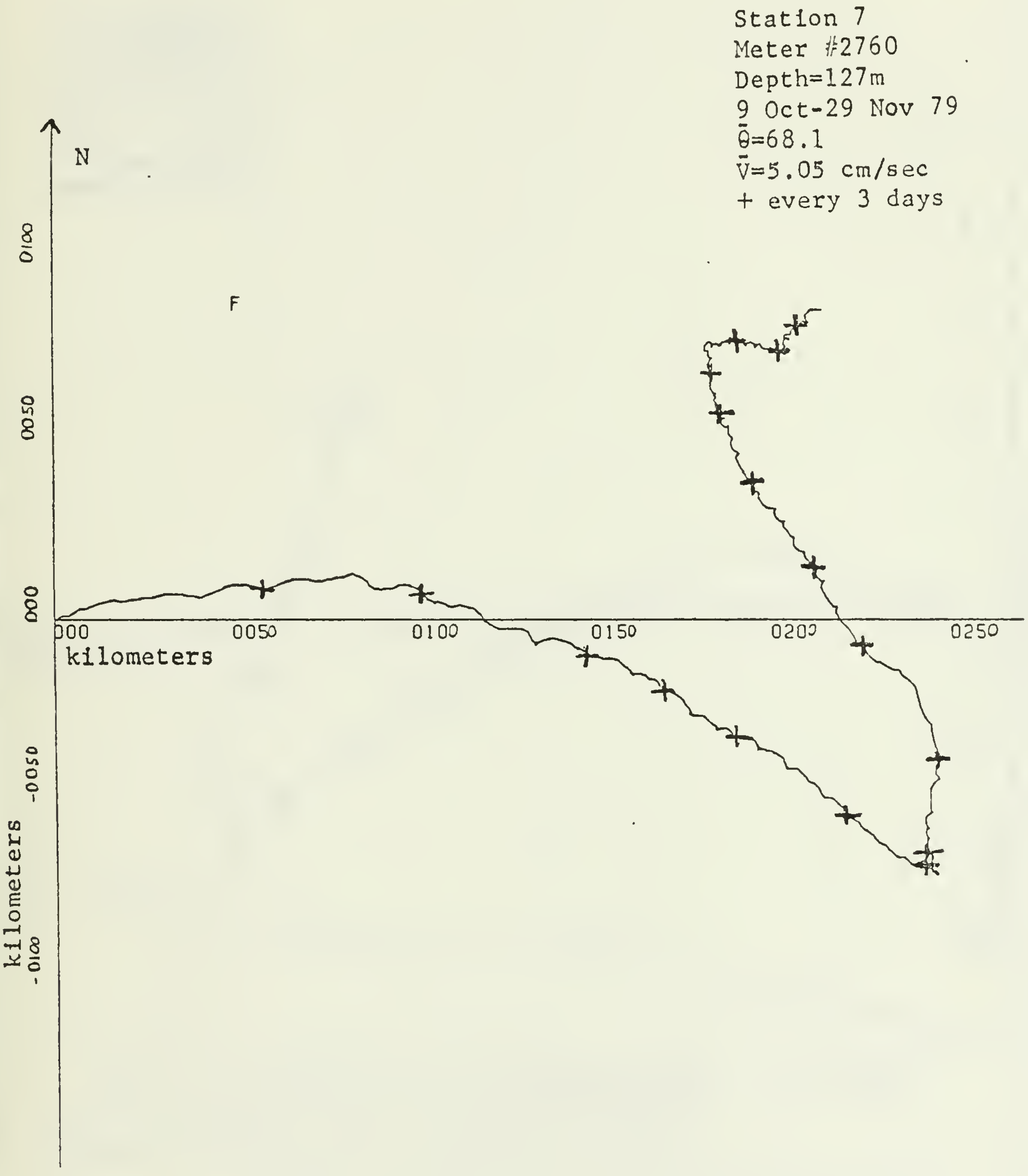


Figure 56. Progressive vector diagram for the current meter at 127 m depth at Station 7 from 9 October to 29 November 1979.

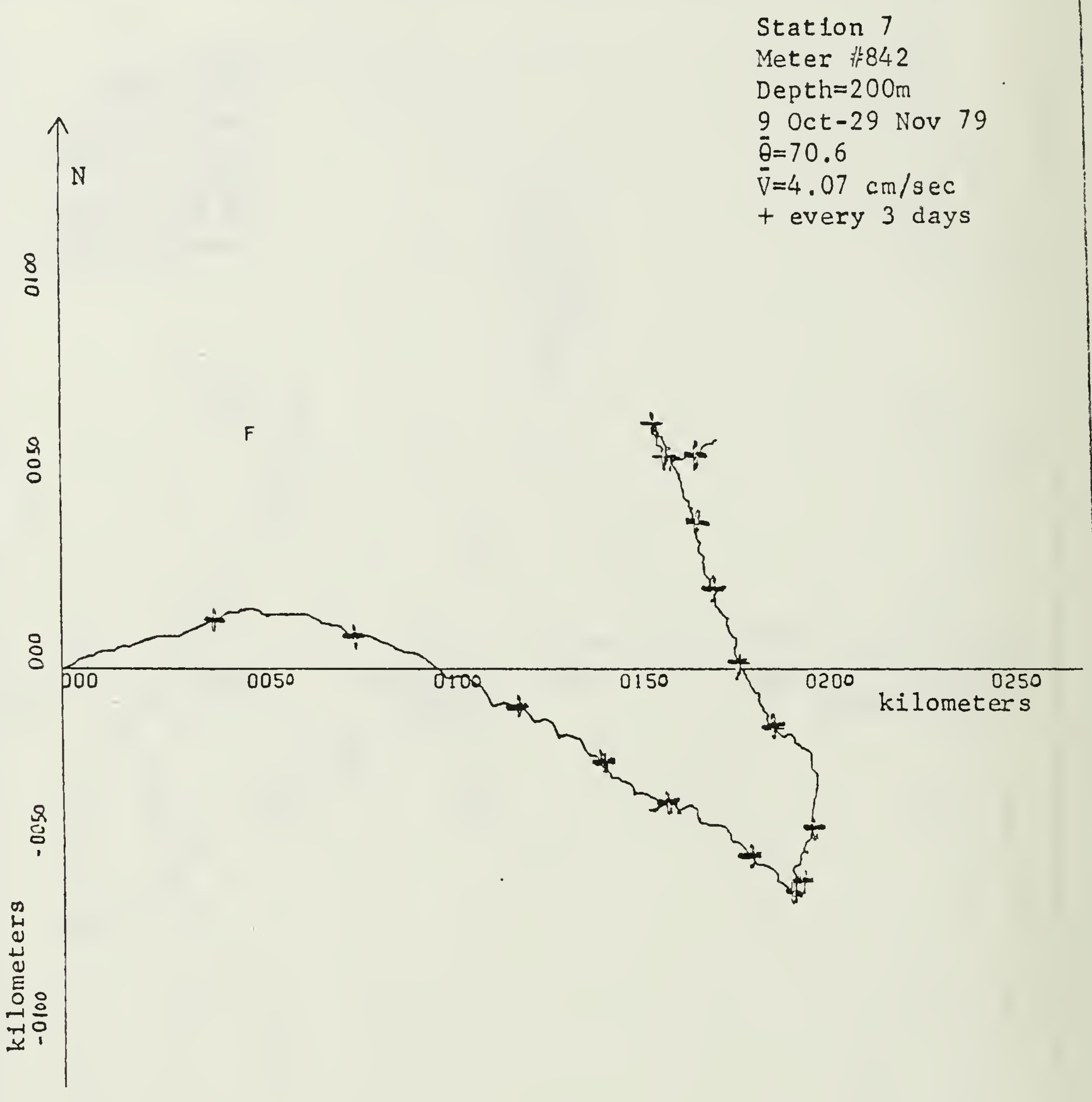


Figure 57. Progressive vector diagram for the current meter at 200 m depth at Station 7 from 9 October to 29 November 1979.

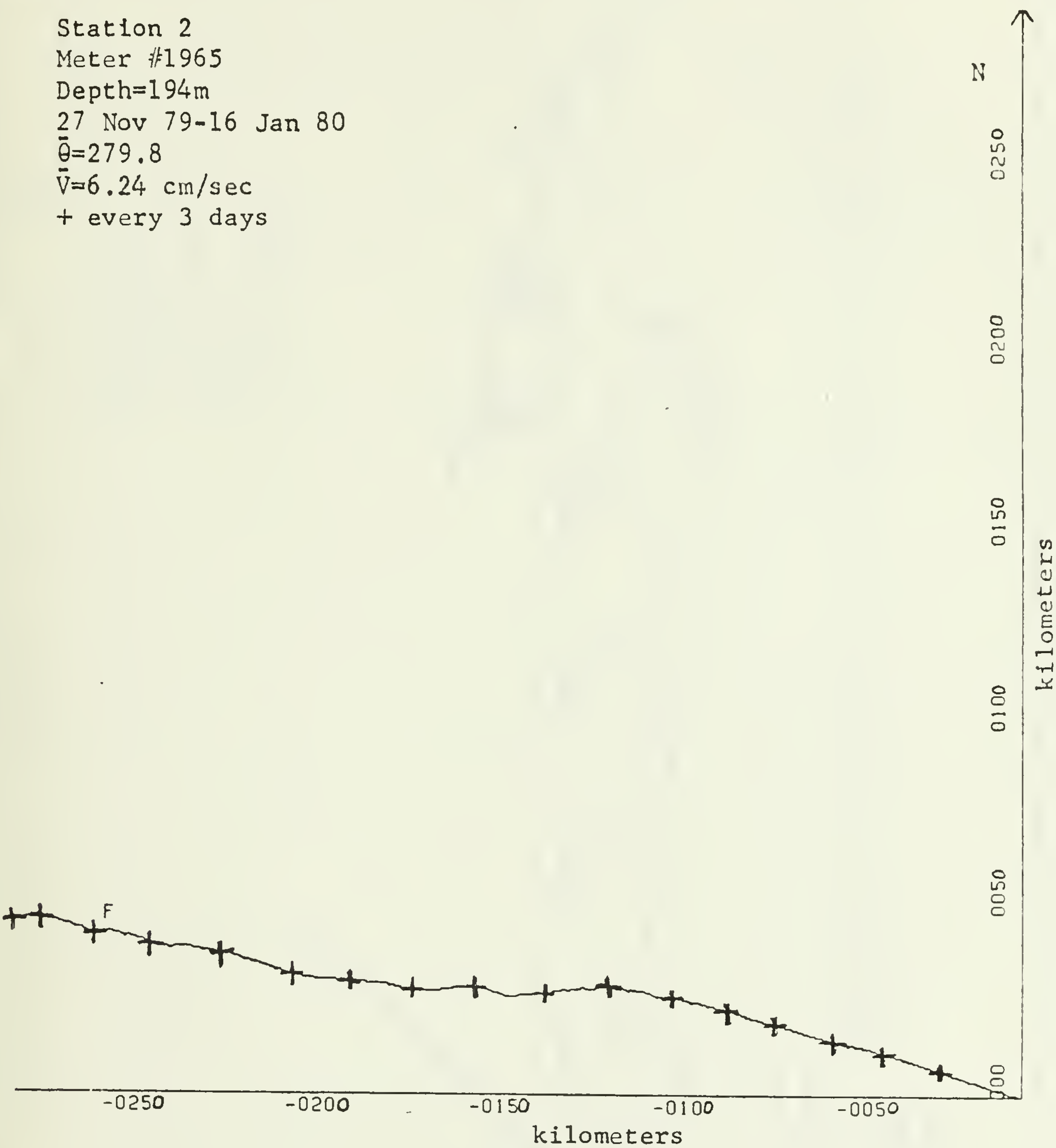


Figure 58. Progressive vector diagram for the current meter at 169 m depth at Station 2 from 27 November 1979 to 16 January 1980.

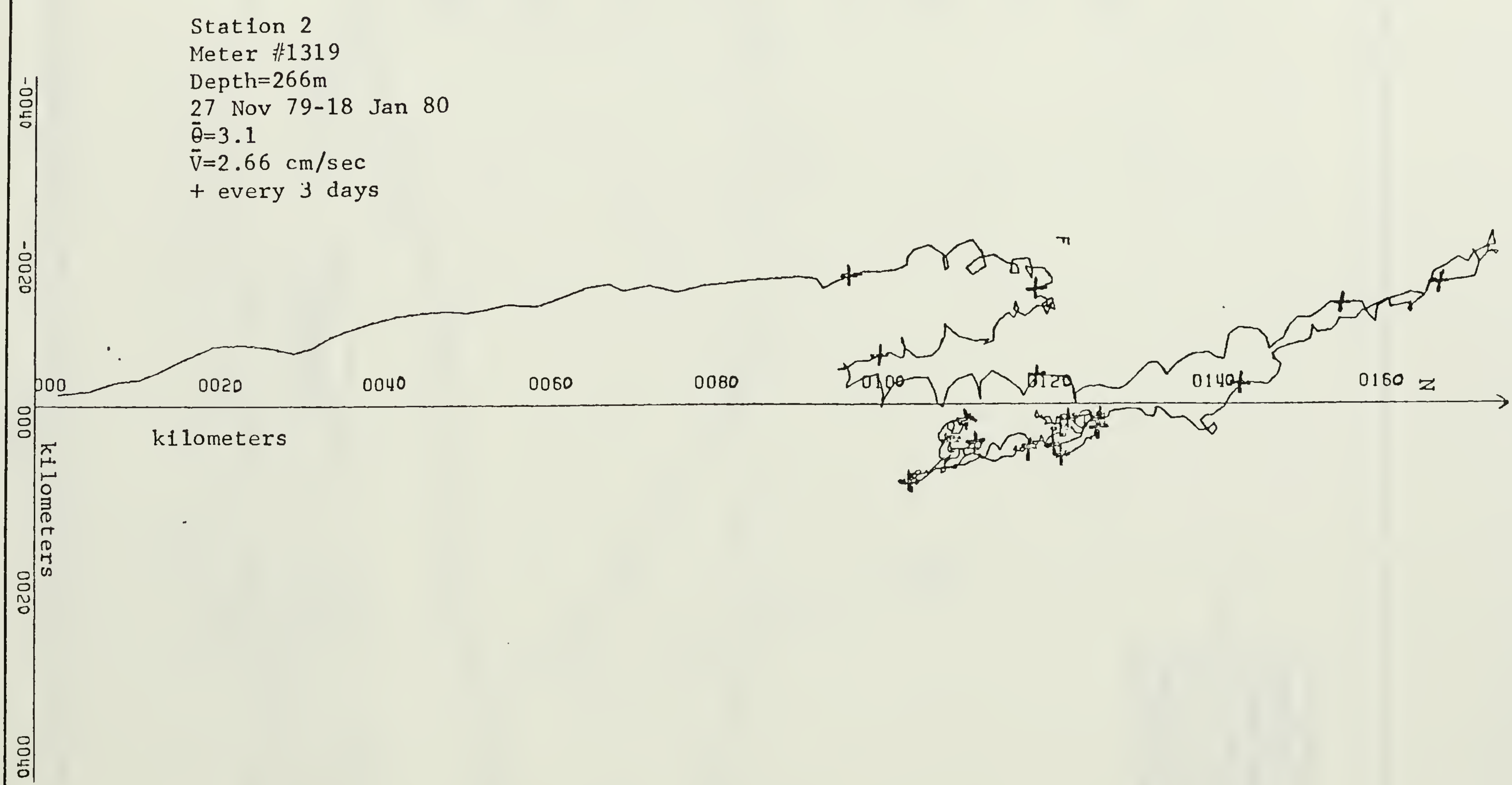


Figure 59. Progressive vector diagram for the current meter at 266 m depth at Station 2 from 27 November 1979 to 18 January 1980.

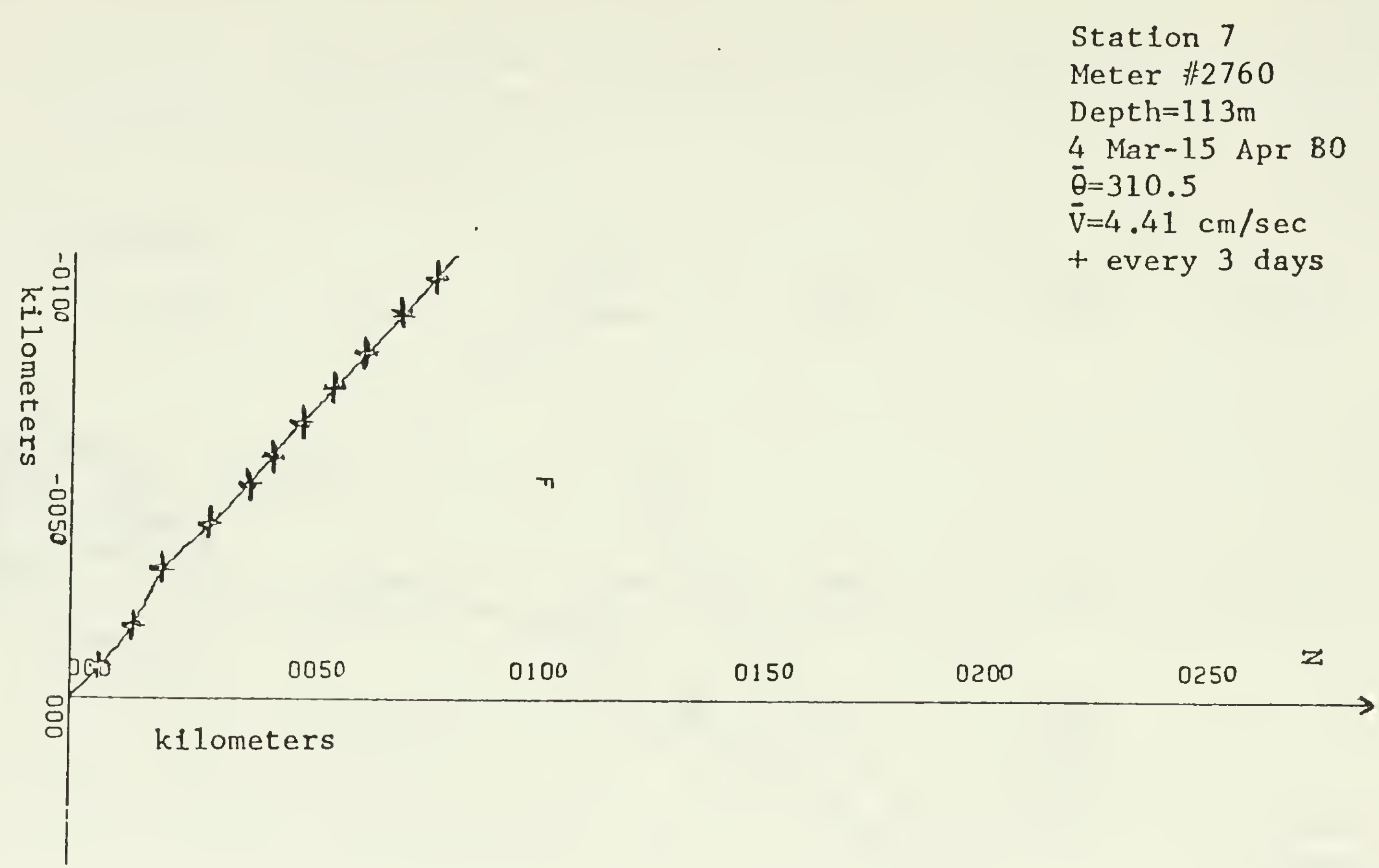


Figure 60. Progressive vector diagram for the current meter at 113 m depth at Station 7 from 4 March to 15 April 1980.

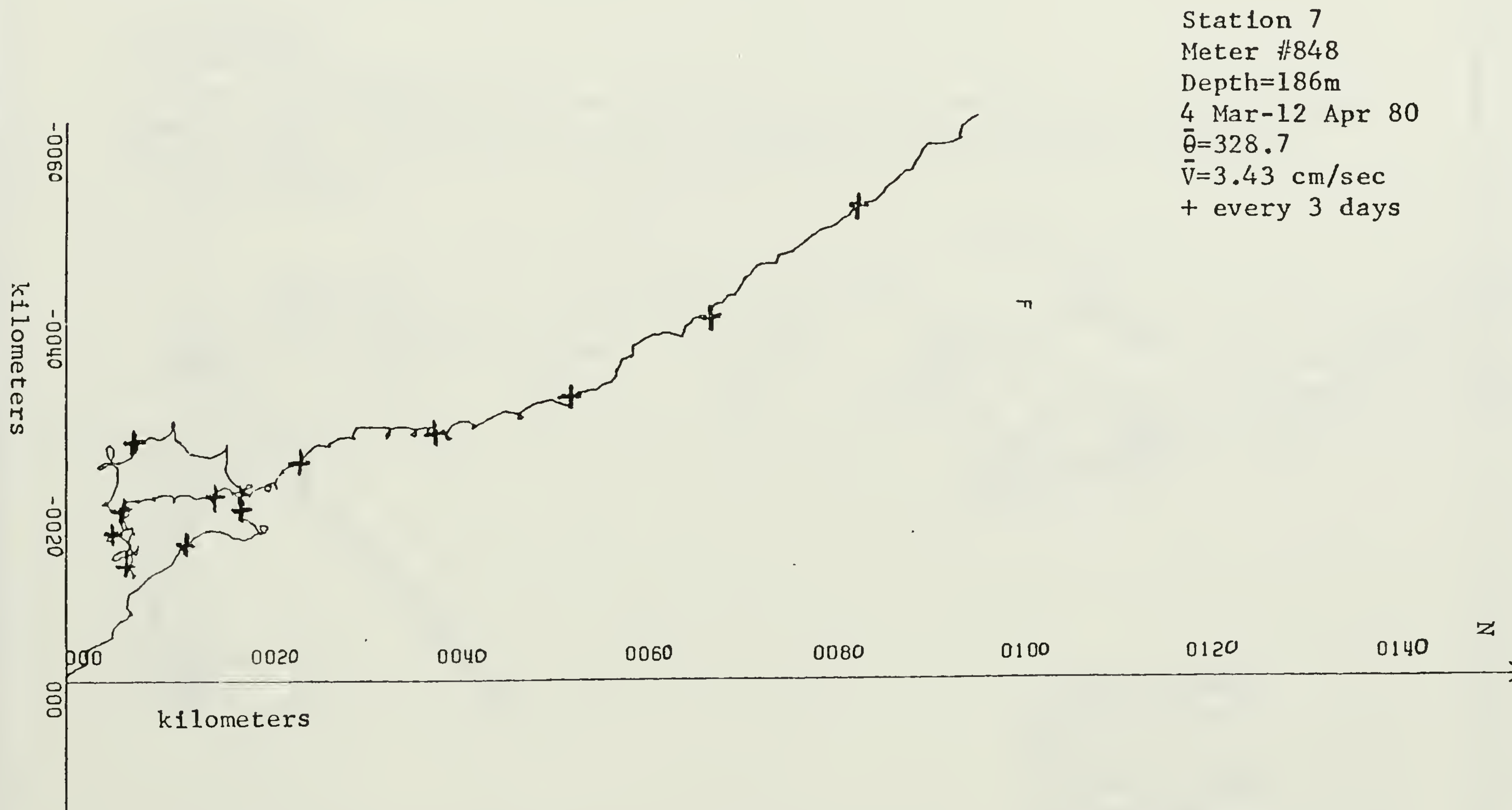


Figure 61. Progressive vector diagram for the current meter at 186 m depth at Station 7 from 4 March to 12 April 1980.

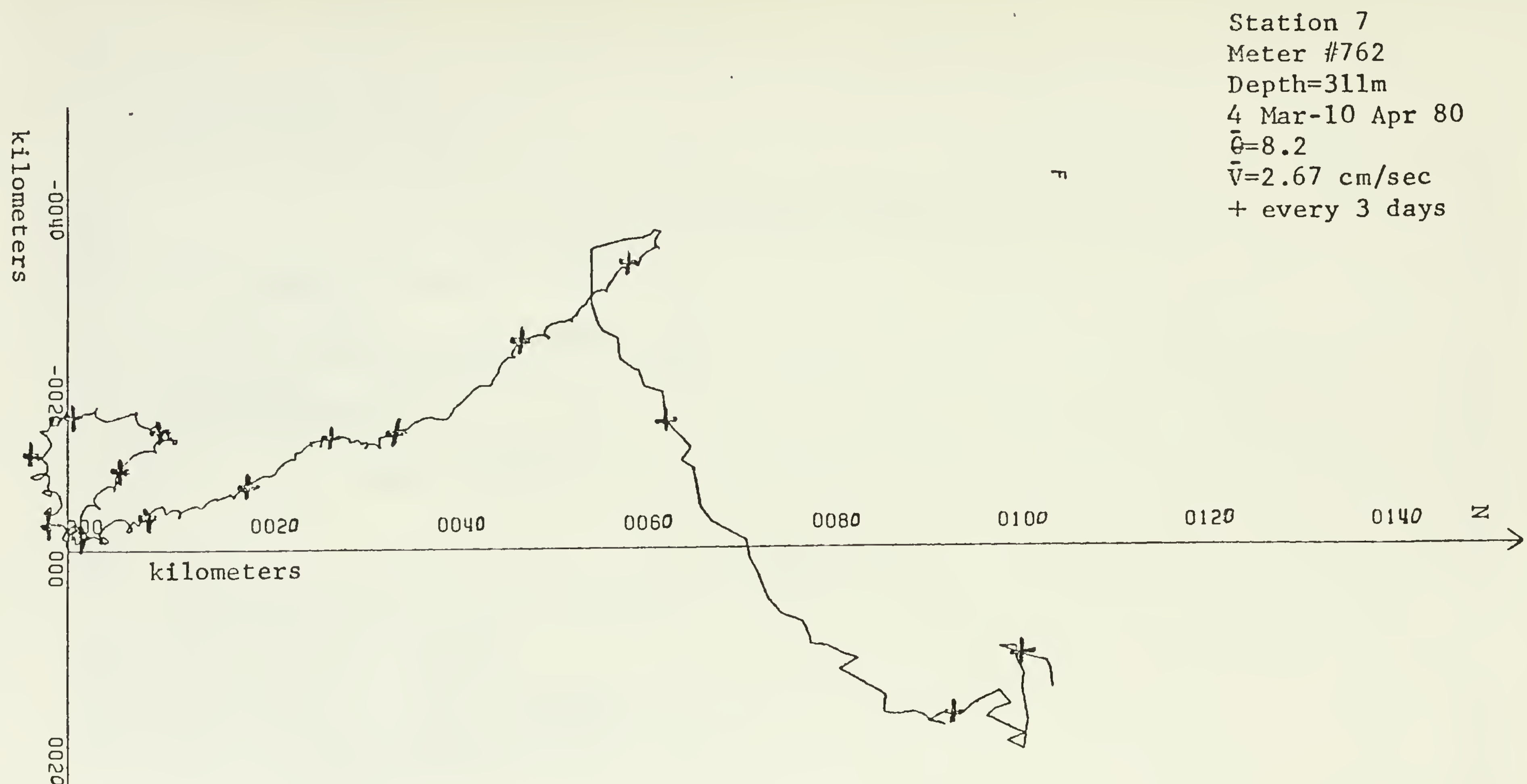


Figure 62. Progressive vector diagram for the current meter at 311 m depth at Station 7 from 4 March to 10 April 1980.

APPENDIX D: COMPUTER PROGRAM LISTINGS

```
C     .THIS PLI PROGRAM FORMATS THE AACERAA CURRENT METER DATA INPUT
C      SO THAT IT IS FORTRAN READABLE. WRITTEN BY HANS DOELMAN NPS
C      COMPUTER CENTER.
 BITS: PROC OPTIONS(MAIN);
 DCL INPUTF FILE RECORD ENV(CONSECUTIVE);
 DCL OUTPUTF FILE RECORD ENV(CONSECUTIVE);
 DCL FIELDX CHAR(512) VARYING STATIC;
 DCL FIELDY(512) CHAR(1) BASED(Q);
 DCL 1 SYNCBIT(512) BASED(P),
       2 B12 BIT(2),
       2 SYNCB BIT(1),
       2 B45678 BIT(5);
 DCL (P,Q) POINTER STATIC;
 ON ENDFILE(SYSIN) GOTO NCKCUNT;
 ON ENDFILE(INPUTF) GOTO THEEND;
 NOKCUNT:
 OPEN FILE(INPUTF) INPUT;
 OPEN FILE(OUTPUTF) OUTPUT;
 P = ADDR(FIELDX);
 KOUT, KCUNTER = 0;
 KK=0;
 MAXK=183;
 I=0;
  LOOP:
 IF KK>=MAXK THEN GOTO THEEND;
 KK=KK+1;
 READ FILE(INPUTF) INTO(FIELDX);
 K = LENGTH(FIELDX);
 DO J=1 TO K;
 IF I=0 | I>5 THEN DO;
 IF SYNCBIT.SYNCB(J) = '1'B THEN DO;
 I = 0;
 END; /* IF SYNC.BIT */
 IF SYNCBIT.SYNCB(J+1)='1'B THEN DO;
 GOTO XX;
 END;
 END;
 I = I+1;
 IF I < 7 THEN DO;
 IF I=1 THEN PUT SKIP(1);
 Q = ADDR(FIELDY(J));
 CALL STOREM (Q,I);
 END; /* IF I < 7 */
 J=J+1;
 XX:
 END; /* DO J = 1 TO K */
 GOTO LOOP;
  THEEND:
```

```
PUT EDIT (KK, 'BLOCKS READ',
          KOUT, 'RECORDS WRITTEN')
         (SKIP(1), F(6), A, F(6), A);
 STOREM: PROC (P,I);
DCL OUTFIELD(6) BIT(16) STATIC;
DCL OUTI(6) FIXED BIN(15) BASED(Q);
 DCL Q POINTER STATIC ;
DCL P POINTER;
DCL INFIELD BIT(16) BASED(P);
  Q = ADDR(OUTFIELD(1)) ;
SUBSTR(OUTFIELD(I),1,6) = '000000'B;
DO II=1 TO 5;
SUBSTR(OUTFIELD(I),II+11,1)=SUBSTR(INFIELD,II+3,1);
SUBSTR(OUTFIELD(I),II+6,1)=SUBSTR(INFIELD,II+11);
END;
PUT EDIT(OUTI(I))(X(4),F(6));
IF I = 6 THEN DO;
KOUT = KOUT + 1;
WRITE FILE(OUTPUTF) FROM(OUTFIELD);
END; /* THE IF I = 6 */
END; /* STOREM */
END; /* THE PROGRAM */
```

```
C     THIS PROGRAM APPLIES CALIBRATION PARAMETERS TC AANDERAA CURRENT
C     METER DATA, ACCORDING TO EACH INDIVIDUAL CURRENT METER'S
C     SPECIFICATIONS.
      INTEGER * 2 AR(50000)
      REAL XXX(6) /6*0./
      M=7
      I1=1
      I2=6
      IR=1
C
C  READ IN RAW DATA.
C
 22   READ(2,23,END=90)(AR(I),I=I1,I2)
 23   FORMAT(6A2)
      I1=I2+1
      I2=I2+6
      GO TC 22
C
C  LOCATE REF NUMBER IN THE RECORD.
C     USE A WINDOW OF APPROXIMATELY 20, IN CASE SYNCBIT SLIPS.
C
 90   IF (AR(M).LE.970.AND.AR(M).GE.940) GC TC 5
      M=M+1
      GO TO 90
C     IF REF* OUTSIDE WINDOW, DATA CONSIDERED FAULTY. ZERO OUT ALL
C     VALUES.
 5    IF (AR(M).GE.971.AND.AR(M).LE.939) GC TC 10
C
C     CALIBRATION PARAMETERS APPLIED. FORMULAS ARE FROM AANDERAA
C     OPERATION MANUAL. SALINITY AND PRESSURE SENSORS  ARE NOT USED.
      T=-2.462+(.02277*AR(M+1))-(.1344*(10.**(-5))*(AR(M+1)**2))+
     1  (.1937*(10.**(-8))*(AR(M+1)**3))
      S=0.0
      P=1023.
      D=0.352*AR(M+4)
      IF (AR(M+5).EQ. 0.) GO TC 50
      V= 1.5 + 168*AR(M+5)/600
      GO TC 60
 50   V=0.0
 60   REF=AR(M)
      WRITE (6,150) IR,REF,T,S,P,D,V
 150  FORMAT(' ',4X,I6,6(4X,F7.2))
C     WRITE CALIBRATED DATA VALUES (10 MINUTE) TC MASS STORAGE.
      WRITE (1) IR,REF,T,S,P,D,V
      IR=IR+1
      M=M+6
      IF (M.GT.50000) GC TC 100
      GO TC 5
```

```
10    WRITE (6,150) IR,XXX
      WRITE (1) IR,XXX
      IR=IR+1
      IF (N.GT.50000) GO TO 100
      N=N+6
      GO TO 5
100   ENDFILE 1
      STOP
      END
```

```
C     THIS PROGRAM USES TEN MINUTE CALIBRATED DATA VALUES AS INPUT.
C     MISSING RECORDS ARE FILLED IN AND A BINOMIAL FILTER IS USED TO
C     CREATE HOURLY VALUES. FOUR PLOTS ARE PRODUCED;CURRENT DIRECTION
C     & SPEED VS TIME, U COMPONENTS VS TIME, V COMPONENT VS TIME, AND
C     TEMPERATURE VS TIME.
      DIMENSION IR(10000),DIR(10000),SPD(10000),AR(6),REF(10000),
     1U(10000),V(10000),T(10000),HRSPD(1700),TRU(10000),THETA(10000),
     1  HOURU(1700),HOURV(1700),HOURT(1700),TEM(10000)
   10 FORMAT (1X,I10,2F10.2)
      J=0
C
C     READ DATA FROM MASS STORAGE
C
   20   READ(L,END=25) II,AR
        IR(II)=II
        REF(II)=AR(1)
        TEM(II)=AR(2)
        SAL=AR(3)
        PRES=AR(4)
        DIR(II)=AR(5)
        SPD(II)=AR(6)
        GO TO 20
   25 CONTINUE
      NPTS=IR(II)
C
C  CREATE ARTIFICIAL VALUES FOR MISSING RECORDS.  (THIS SUBROUTINE
C  LEAVES THE REFERENCE NUMBER ZERO FOR READY IDENTIFICATION OF
C  ARTIFICIAL VALUES.)
C
      MPTS=NPTS-2
      DO 7 I=3,MPTS
C     WARNING: CURRENT SPEEDS GREATER THAN 100 CM/SEC ARE NOT  ACCEPTED
C     HERE BUT SUBSTITUTED WITH INTERPOLATED VALUES.
      IF(SPD(I).GE.100) GO TO 6
        IF (REF(I).NE.0.)  GO TO 5
 6      CALL FILLER (I,SPD,DIR,SPDOUT,DIROUT)
        SPD(I)=SPDOUT
        DIR(I)=DIROUT
C     INSURE TEMPERATURE VALUES ARE WITHIN ACCEPTABLE LIMITS. AVOID
C     INCORPORATING FAULTY DATA BY SEARCHING DOWN THE RECORD FOR AN
C     ACCEPTABLE VALUE.
  5   IF(TEM(I).GE.5.0.AND.TEM(I).LE.12.0)   GO TO 7
      J=I
 2    IF (TEM(J+1).GE.5.0.AND.TEM(J+1).LE.12.0)GO TO 3
      J=J+1
      GO TO 2
 3    TNEW=(TEM(I-1)+TEM(J+1))/2.
      TEM(I)=TNEW
```

```
 7    CONTINUE
C
C  CREATE A REPRESENTATIVE HOURLY CURRENT VALUE FROM THE 10 MINUTE
C  RECORDS..
C
         NPTS6=(NPTS/6)
         CALL RMEAN(NPTS,NPTS6,SPD,DIR,HRSPD,U,V,T,TRU,THETA,TEM,
     1   HOURU,HOURV,HOURT,RHOT)
C
      CREATE DATA PLOTS.
C
      NPTS=NPTS6
      NPTS2=NPTS+2
      CALL STKPLT(NPTS,NPTS2,IF,HRSPD,HOURU,HOURV,HOURT,RHOT)
      STOP
      END
      SUBROUTINE FILLER (I,SPD,DIR,SPDOUT,DIROUT)
C
C  SUBROUTINE FILLER CREATES SPEED AND DIRECTION VALUES FOR THE CURRENT
C
C  METER RECORD.  THIS IS DONE TO PROVIDE REASONABLE APPROXIMATIONS
C  FOR THE OCCASIONAL RECORD MISSED DUE TO INSTRUMENT (METER)
C     MALFUNCTION. THE AVERAGING ROUTINE AVOIDS INCORPORATING FAULTY
C     DATA.
C
C
      DIMENSION DIR(1),SPD(1)
      J=I
 8    IF(SPD(J+1).LE.100.)GO TO 9
      J=J+1
      GO TO 8
 9    SPDOUT=(SPD(I-1)+SPD(J+1))/2.
      IF (DIR(I-1).LE.90..AND.DIR(I+1).GT.270.)  GO TO 10
      IF(DIR(I-1).GT.270..AND.DIR(I+1).LE.90.)  GO TO 10
      IF (DIR(I-1)-DIR(I+1).GT.180.)  GO TO 15
      IF (DIR(I+1)-DIR(I-1).GT.180.)  GO TO 15
      DIROUT=(DIR(I-1)+DIR(I+1))/2.
      GO TO 20
 10      DIROUT=(DIR(I-1)-DIR(I+1))/2.+DIR(I+1)+180.
         IF(DIROUT.GE.360.)  DIROUT=DIROUT-360.
         IF(DIROUT.GE.360.)  DIROUT=DIROUT-360.
         GO TO 20
 15      DIROUT=(DIR(I-1)+DIR(I+1))/2.+180.
         GO TO 20
 20   CONTINUE
      RETURN
      END
      SUBROUTINE RMEAN(NPTS,NPTS6,SPD,DIR,HRSPD,U,V,T,TRU,THETA,
```

```
     1   TEM,HCURU,HCURV,HCURT,RHCT)
C
C
C        SUBROUTINE RMEAN CREATES HOURLY CURRENT VALUES AND TEMPERATURE
C        VALUES FROM A 9-POINT WEIGHTED BINOMIAL FILTER.
C
         DIMENSION SPD(NPTS),DIR(NPTS),HRSPD(NPTS6),HCURU(NPTS6),
     1     HCURV(NPTS6),HCURT(NPTS6),U(NPTS),V(NPTS),T(NPTS),TRU(NPTS),
     1     THETA(NPTS),TEM(NPTS)
         MPTS=NPTS-8
         DO 10 I=1,NPTS
C        APPLY VARIANCE CORRECTION TO MAGNETIC DIRECTIONS.
         VAR=15.17
         TRU(I)=DIR(I)+VAR
         IF (TRU(I).GE.360.) TRU(I)=TRU(I)-360.
C        CONVERT TO RADIANS.
         THETA(I)=TRU(I)*(.017453)
         U(I)=SPD(I)*SIN(THETA(I))
         V(I)=SPD(I)*COS(THETA(I))
C        WRITE 10 MINUTE U & V COMPONENTS TO MASS STORAGE.
         WRITE (2,250) U(I),V(I)
    250  FORMAT (2F12.5)
    10   CONTINUE
         J=0
         K=0.
         HOT=0.
         DO 20 I=1,MPTS,6
         J=J+1
         U1=1.*U(I)
         U2=8.*U(I+1)
         U3=28.*U(I+2)
         U4=56.*U(I+3)
         U5=70.*U(I+4)
         U6=56.*U(I+5)
         U7=28.*U(I+6)
         U8=8.*U(I+7)
         U9=1.*U(I+8)
         HCURU(J)=(U1+U2+U3+U4+U5+U6+U7+U8+U9)/
     1          (2.*1.+2.*8.+2.*28.+2.*56.+70.)
         V1=1.*V(I)
         V2=8.*V(I+1)
         V3=28.*V(I+2)
         V4=56.*V(I+3)
         V5=70.*V(I+4)
         V6=56.*V(I+5)
         V7=28.*V(I+6)
         V8=8.*V(I+7)
         V9=1.*V(I+8)
```

```
      HOURV(J)=(V1+V2+V3+V4+V5+V6+V7+V8+V9)/
     1       (2.*1.+2.*8.+2.*28.+2.*56.+70.)
       T1=1.*TEM(I)
      T2=8.*TEM(I+1)
      T3=28.*TEM(I+2)
      T4=56.*TEM(I+3)
      T5=70.*TEM(I+4)
      T6=56.*TEM(I+5)
      T7=28.*TEM(I+6)
      T8=8.*TEM(I+7)
      T9=1.*TEM(I+8)
      HOURT(J)=(T1+T2+T3+T4+T5+T6+T7+T8+T9)/
     1       (2.*1.+2.*8.+2.*28.+2.*56.+70.)
      HRSPD(J)=SQRT((HOURU(J))**2+(HOURV(J))**2)
      IF (HOURT(J).LE.5.5) GO TO 20
      IF (HOURT(J).GE.10.0) GO TO 20
      K=K+1
      HCT=HOURT(J)+HCT
   20 CONTINUE
C     COMPUTE MEAN TEMPERATURE FOR THE RECORD. (VALUE IS SCALED FOR
C     SUBSEQUENT PLOTTING.)
      RHCT= ((HCT/K)*2.0)-14.
      WRITE(6,50) RHCT
   50 FORMAT(1X,F6.2)
      RETURN
      END
      SUBROUTINE STKPLT(NPTS,NPTS2,IR,HRSPD,HOURU,HOURV,HOURT,RHCT)
C
C     SUBROUTINE STKPLOT CREATES A PLOT OF CURRENT VECTORS AS A
C     FUNCTION OF TIME, FOLLOWED BY PLOTS OF U COMPONENTS, V COMPONENTS,
C     AND TEMPERATURE VS TIME. THE USER SHOULD REFER TO THE NAVAL
C     POSTGRADUATE SCHOOL TECHNICAL NOTE NO. 0141-34 IN REGARDS TO
C     PLOTTING PARAMETERS.
C
      DIMENSION IR(NPTS),HRSPD(NPTS2),HOURU(NPTS),HOURV(NPTS),
     1    HOURT(NPTS)
      INTEGER*4 Z1111/Z1111/
      XNPTS=NPTS
      XLEN=(NPTS/20.)+2.
      YLEN=8.
  100 FORMAT('1',8X,1HJ,11X,2HIR,4X,5HHRSPD,9X,
     1 1HU,9X,1HV,9X,1HT,7X,2HY1,8X,2HY1)
  200 FORMAT (1X,I9,3X,I10,6F10.2)
C
C     SET UP THE STICKPLOT
C
      CALL PLOTS (0,0,0)
      CALL FACTOR (0.35)
```

```
      HRSPD(NPTS+1)=-40.
      HRSPD(NPTS+2)=10.
      FVALS=HRSPD(NPTS+1)
      DVS=HRSPD(NPTS+2)
      CALL PLOT(3.,10.,-3)
      CALL AXIS (0.,-5.,'SAMPLE NUMBER',-13,XLEN,0.,0.,20.)
      CALL AXIS(0.,-4.,13HSPEED(CM/SEC),13,YLEN,90.,FVALS,DVS)
      CALL HLINE (0.,XLEN,0.,Z1111)
        WRITE (6,100)
      J=0
C     PLOT THE DATA.
      DO 10 I=1,NPTS
      J=J+1
      CALL PLOT (.05,0.,-3)
      X1=HOURU(I)/DVS
      Y1=HOURV(I)/DVS
        CALL PLOT(X1,Y1,2)
      WRITE(6,200) J,IR(I),HRSPD(I),HOURU(I),HOURV(I),HOURT(I),X1,Y1
   10 CONTINUE
      CALL PLOT (0.,0.,999)
C     SET UP THE U COMPONENT PLOT.
      CALL PLOTS (0,0,0)
      CALL FACTOR (0.35)
      HRSPD(NPTS+1)=-40.
      HRSPD(NPTS+2)=10.
      FVALS=HRSPD(NPTS+1)
      DVS=HRSPD(NPTS+2)
      CALL PLOT(3.,10.,-3)
      CALL AXIS (0.,-5.,'SAMPLE NUMBER',-13,XLEN,0.,0.,20.)
      CALL AXIS(0.,-4.,13HSPEED(CM/SEC),13,YLEN,90.,FVALS,DVS)
      CALL HLINE (0.,XLEN,0.,Z1111)
      CALL PLOT(0.,0.,-3)
      B=0.
C     PLOT THE DATA.
      DO 11 I=1,NPTS
      B=B+.05
      X1=B
      Y1=HOURU(I)/DVS
        CALL PLOT(X1,Y1,2)
   11 CONTINUE
      CALL PLOT (0.,0.,999)
C     SET UP THE V COMPONENT PLOT.
      CALL PLOTS (0,0,0)
      CALL FACTOR (0.35)
      HRSPD(NPTS+1)=-40.
      HRSPD(NPTS+2)=10.
      FVALS=HRSPD(NPTS+1)
      DVS=HRSPD(NPTS+2)
```

```
      CALL PLOT(3.,10.,-3)
      CALL AXIS (0.,-5.,'SAMPLE NUMBER',-13,XLEN,0.,0.,20.)
      CALL AXIS(0.,-4.,13HSPEED(CM/SEC),13,YLEN,90.,FVALS,DVS)
      CALL HLINE (0.,XLEN,0.,Z1111)
      CALL PLOT(0.,0.,-3)
      B=0.
C     PLOT THE DATA.
      DO 12 I=1,NPTS
      B=B+.05
      X1=B
      Y1=HCURV(I)/DVS
        CALL PLOT(X1,Y1,2)
   12 CONTINUE
      CALL PLOT (0.,0.,999)
C     SET UP THE TEMPERATURE PLOT.
      CALL PLOTS (0,0,0)
      CALL FACTOR (0.35)
      CALL PLOT(3.,10.,-3)
      CALL AXIS (0.,-5.,'SAMPLE NUMBER',-13,XLEN,0.,0.,20.)
      CALL AXIS(0.,-4.,13H(TEMPERATURE),13,16.,90.,5.,.5)
      CALL HLINE(0.,XLEN,RHOT,Z1111)
      CALL PLOT (0.,RHOT,+3)
      B=0.
C     PLOT THE DATA.
      DO 13 I=1,NPTS
      B=B+.05
      X1=B
      Y1= (HCURT(I)*2.0)-14.
        CALL PLOT(X1,Y1,2)
   13 CONTINUE
      CALL PLOT (0.,0.,999)
      RETURN
      END
```

```
      DIMENSION REF(10000),DIR(10000),SPD(10000),AR(6),
     1 ALONG(10000),CROSS(10000),YYY(10000),F1(10000),PERIOD(10000),
     2 FREQUE(10000),U(10000),V(10000),TRT(10000),THT(10000)
C
C   PROGRAM TO EVALUATE THE ENERGY DENSITY SPECTRUM OF OBSERVED CURRENTS
C   THROUGH THEIR ALONGSHORE AND CROSS SHELF COMPONENTS.
C
   10 FORMAT (1X,I10,2F10.2)
C
C   JDATA IS THE (HOURLY) DATA POINT AT WHICH THE ENERGY SPECTRA
C   PROGRAM SHOULD BEGIN TO LOOK AT DATA.  IT DOES NOT ALWAYS START AT
C   1 SINCE SOME METERS HAVE A LONG LEADER WITH NO RELEVANT VALUES.
C
      JDATA=5
C
C   READ RAW DATA FROM MAGNETIC TAPE.
C
   20    READ(1,END=25) II,AR
         NPTS=II
         REF(II)=AR(1)
         TEM=AR(2)
         SAL=AR(3)
         PRES=AR(4)
         DIR(II)=AR(5)
         SPD(II)=AR(6)
         GO TO 20
   25 CONTINUE
C
C   CREATE ARTIFICIAL VALUES FOR MISSING RECORDS.  (THIS SUBROUTINE
C   LEAVES THE REFERENCE NUMBER ZERO FOR READY IDENTIFICATION OF
C   ARTIFICIAL VALUES.)
C
      MPTS=NPTS-2
      DO 5  I=3,MPTS
      IF(SPD(I).GE.100) GO TO 6
      IF (REF(I).NE.0.)  GO TO 5
    6    CALL FILLER (I,SPD,DIR,SPDOUT,DIROUT)
         SPD(I)=SPDOUT
         DIR(I)=DIROUT
    5 CONTINUE
      DO 11 I=1,NPTS
      VAR=30.17
      TRT(I)=DIR(I)+VAR
      IF (TRT(I).GE.360.)TRT(I)=TRT(I)-360.
      THT(I)=TRT(I)*(.017453)
      U(I)=SPD(I)*SIN(THT(I))
      V(I)=SPD(I)*COS(THT(I))
      CROSS(I)=U(I)
```

```
      ALONG(I)=V(I)
11    CONTINUE
      DO 80  J=1, 4
        IF  (J.EQ.1)  GO TO 40
        IF  (J.EQ.2)  GO TO 50
        IF  (J.EQ.3)  GO TO 40
        IF  (J.EQ.4)  GO TO 60
50     CALL BCXCAR(ALONG,NPTS,24,1,NOUT1)
       CALL BCXCAR(ALONG,NPTS,24,1,NOUT1)
       CALL BCXCAR(ALONG,NPTS,25,1,NOUT1)
       GO TO 40
60     CALL BCXCAR(CROSS,NPTS,24,1,NOUT1)
       CALL BCXCAR(CROSS,NPTS,24,1,NOUT1)
       CALL BCXCAR(CROSS,NPTS,25,1,NOUT1)
40    M=11
      MS=1
      DT=(1./6.)
        JSTART=JDATA
      DO 45 I=1,4500
          IF  (J.GE.3)   GO TO 41
          YYY(I)=ALONG(JSTART)
          GO TO 43
41        YYY(I)=CROSS(JSTART)
43        JSTART=JSTART+1
45     CONTINUE
        IF  (J.GE.3)  GO TO 70
      CALL PREPFA(M,MS,DT,YYY,F1,PERIOD,FREQUE,NF)
        IF  (J.EQ.1)  GO TO 80
        CALL PLOT (0.0,0.0,999)
        GO TO 80
70    CALL PREPFA(M,MS,DT,YYY,F1,PERIOD,FREQUE,NF)
80    CONTINUE
      CALL PLOT(0.0,0.0,+999)
      STOP
      END
      SUBROUTINE FILLER  (I,SPD,DIR,SPDOUT,DIRCUT)
C
C
C   SUBROUTINE FILLER CREATES SPEED AND DIRECTION VALUES FOR THE CURRENT
C   METER RECORD.  THIS IS DONE TO PROVIDE REASONABLE APPROXIMATIONS
C   FOR THE OCCASIONAL RECORD MISSED DUE TO INSTRUMENT (METER)
C   MALFUNCTION.
C
C
      DIMENSION DIR(1),SPD(1)
      J=I
8     IF(SPD(J+1).LE.100.)GO TO 9
      J=J+1
```

```
      GO TO 8
9     SPDOUT=(SPD(I-1)+SPD(J+1))/2.
      IF (DIR(I-1).LE.90..AND.DIR(I+1).GT.270.)  GO TO 10
      IF(DIR(I-1).GT.270..AND.DIR(I+1).LE.90.)  GO TO 10
      IF (DIR(I-1)-DIR(I+1).GT.180.)  GO TO 15
      IF (DIR(I+1)-DIR(I-1).GT.180.)  GO TO 15
      DIROUT=(DIR(I-1)+DIR(I+1))/2.
      GO TO 20
 10     DIROUT=(DIR(I-1)-DIR(I+1))/2.+DIR(I+1)+180.
        IF(DIROUT.GE.360.)  DIROUT=DIROUT-360.
        IF(DIROUT.GE.360.)  DIROUT=DIROUT-360.
        GO TO 20
 15     DIROUT=(DIR(I-1)+DIR(I+1))/2.+180.
        GO TO 20
 20   CONTINUE
      RETURN
      END
      SUBROUTINE BOXCAR (SL,NIN,LTH,IDEC,NOUT)
      REAL*4 SL(6200)
      NOUT=0
      ISTART=1
 20   IEND=ISTART+LTH-1
      IF (IEND.GT.NIN) RETURN
      SUM=0.
      DO 30 I=ISTART,IEND
 30   SUM=SUM+SL(I)
      NOUT=NOUT+1
      SL (NOUT)=SUM/FLOAT(LTH)
      ISTART=ISTART+IDEC
      GO TO 20
      END
      SUBROUTINE PREPFA(M,MS,DT,YYY,F1,PERIOD,FREQUE,NF)
      DIMENSION YYY(5000),INV(5000),S(5000),F1S(5000),C(5000),F1(5000)
      DIMENSION ART(5000),PERIOD(5000),FREQUE(5000)
240   FORMAT('1',' POWER SPECTRUM IS CALCULATED',/' TOTAL NUMBER OF SAMP
     1LES=',I5,/1X,'THE TIME INCREMENT =',F5.3,/1X,'THE NUMBER OF DEGREE
     2S OF FREEDOM FOR EACH SPECTRAL ESTIMATE =',I5,///)
250   FORMAT('0','STATISTICS OF SAMPLE NUMBER =',I4)
260   FORMAT('0','MEAN VALUE =',F12.3,3X,'VARIANCE =',F12.3,3X,'SKEWNESS
     1 =',F12.3,3X,'KURTOSIS =',F8.3,3X,'STD DEVIATION =',F12.3)
270   FORMAT('0',T10,F12.3,T25,F12.3,T40,F12.3)
      NM=2*2**M
      NM1=NM-1
      N=NM*MS
      NF=2**M+1
      NFREDM=MS*2
      T=NM*DT
      WRITE(6,240) N, DT, NFREDM
```

```
      DO 510  I=1,NF
510     F1(I)=0.
      IZ=0
      K=0
      DO 21  I27=1,N
       ART(I27)=YYY(I27)
   21 CONTINUE
      CALL AVERA(ART,N,AMEAN)
      DO 22  I28=1,N
       C(I28)=ART(I28)-AMEAN
   22 CONTINUE
      DO 520 MI=1,MS
      K=K+1
      DO 530 JJ=1,NM
      IZ=IZ+1
530     F1S(JJ)=C(IZ)
      WRITE (6,250) K
      CALL TREND(F1S,NM,DT,U11,U21,U31,U41,URMS1)
      CALL SPEC(F1S,M,INV,S,IFERR)
      WRITE (6,260) U11,U21,U31,U41,URMS1
      DO 540  I=1,NF
540     F1(I)=F1S(I)+F1(I)
520     CONTINUE
      DO 550  I=1,NF
      F1(I)=F1(I)*T/(2.*MS)
      IF(I.EQ.1)GO TO 23
      PERIOD(I)=((FLOAT(NM))*(DT))/FLOAT(I-1)
      FREQUE(I)=1.0/PERIOD(I)
      IF(F1(I).LE.10.0)GO TO 550
      GO TO 24
   23 PERIOD(I)=FLOAT(NM)
      FREQUE(I)=0.0
   24 WRITE(6,270)F1(I),PERIOD(I),FREQUE(I)
  550 CONTINUE
      CALL FLCTG(FREQUE,F1,NF,1,1,1,'FREQUENCY (CYCLES PER HOUR)',27,'PO
     1WER DENSITY FUNCTION (CM SQ. HOUR)',36,0.0,0.2,0.0,0.0,13.0,6.0)
      RETURN
      END
      SUBROUTINE   SPEC   (F1,M,INV,S,IFERR)
C
C     SUBROUTINE TO CALCULATE THE POWER SPECTRUM OF A SIGNAL USING RHARM
C
      DIMENSION INV(515),S(515),F1(515)
      CALL RHARM(F1,M,INV,S,IFERR)
      NP=2**M-1
      NF=2**M+1
      NM=2*2**M
      NL=NM+1
```

```
      F1(1)=F1(1)*F1(1)
      DO 500 I=1,NP
      J=2*I+1
      L=I+1
      XR=F1(J)*F1(J)
      XI=F1(J+1)*F1(J+1)
      F1(L)=XR+XI
500   CONTINUE
      F1(NF)=F1(NL)**2
      RETURN
      END
      SUBROUTINE TREND(FX,NTS,DT,FMEAN,U2,U3,U4,URMS)
C     SUBROUTINE TREND EDITS CALIBRATES AND DETRENDS DATA
      DIMENSION FX(NTS)
C     EDITING DATA
C
C
      FNTS=NTS
C     COMPUTING THE LINEAR TREND
      SUMF=0.0
      DO 101 I=1,NTS
101   SUMF=SUMF+FX(I)
      SUMF1=0.0
      DO 102  I=1,NTS
      XI=I
102   SUMF1=SUMF1+XI*FX(I)
      XNM1=NTS-1
      XNP1=NTS+1
      XM=(1.0/DT)*(12.0*SUMF1/(FNTS*XNM1*XNP1)-6.0*SUMF/(XNM1*FNTS))
      B=SUMF/FNTS-XM*XNP1*DT/2.0
      FMEAN=SUMF/FNTS
C
C
      WRITE (6,9) FMEAN,XM,B
9     FORMAT(3X,'MEAN=', F10.5,3X,'SLOPE =',F10.5,3X,'INTERCEPT =',F10.5
     1,//)
      DO  103 I=1,NTS
      XI=I
103   FX(I)=FX(I)-(B+XM*XI*DT)
C     SUBROUTINE FOR CALCULATING VARIANCE, STD DEV, SKEWNESS, KURTOSIS
      U2=0.0
      U3=0.0
      U4=0.0
      SUMU2=0.0
      SUMU3=0.0
      SUMU4=0.0
      DO 151 I=1,NTS
      U2=FX(I)*FX(I)
```

```
      U3=U2*FX(I)
      U4=U3*FX(I)
      SUMU2=SUMU2+U2
      SUMU3=SUMU3+U3
      SUMU4=SUMU4+U4
151   CONTINUE
      FNTS=NTS
      U2=SUMU2/FNTS
      URMS=SQRT(U2)
      U3=SUMU3/(FNTS*U2*URMS)
      U4=SUMU4/(FNTS*U2*U2)
      RETURN
      END
      SUBROUTINE PAGE
   10 FORMAT ('1')
      WRITE (6,10)
      RETURN
      END
      SUBROUTINE AVERA (A,NPTS, AMEAN)
      DIMENSION A(NPTS)
      SUM=0.0
      DO 100  I=1,NPTS
      SUM=SUM+A(I)
100   CONTINUE
      AMEAN=SUM/FLOAT(NPTS)
      RETURN
      END
```

```
C       -----------TRAJEC----------
C       PROGRAM TRAJEC TO PLOT PROGRESSIVE VECTOR DIAGRAMS OF CURRENT
C       METER DATA.  IF COMPONENTS ARE GIVEN, WE SET COMP=T.  IF SPEED
C       AND DIRECTION ARE GIVEN, WE SET COMP=F AND READ SPEED INTO U AND
C       DIRECTION INTO V.  THE NUMBER OF POINTS IS GIVEN AS N.  WE PLOT
C       EVERY NP POINTS AND PUT A + ON EVERY NX OF THE NP POINTS.
C       PLOTTED POINTS CANNOT EXCEED 900 IF DRAW IS CALLED.  THE TIME
C       INTERVAL IN HOURS IS DELT.  WE USE OBJECT TIME FORMAT.  THE
C       VECTOR SUMS ARE STORED IN CU AND CV.  IT IS DESIRABLE THAT NP*NX
C       CORRESPOND TO AN INTEGRAL FRACTION OF ONE DAY.  IF PLT IS TRUE,
C       A LINE PLOTTING ROUTINE IS CALLED.  IF RPT IS TRUE, THE VECTOR
C       MEAN IS SUBTRACTED FROM THE DATA AND THE TREATMENT IS REPEATED.
C       PROVISION IS MADE FOR READING AND DISCARDING NSTRT POINTS AT THE
C       BEGINNING.  PROVISION IS MADE TO READ TWO OR MORE FILES IF NFILE
C       IS SET TO 2 OR MORE.  A COMPLETE SET OF DATA CARDS MUST THEN BE
C       SUPPLIED FOR EACH FILE.
C       THIS VERSION PROVIDES FOR READING FROM FILE TO FILE SEQUENTIALLY.
C       IF THEY ARE SEQUENTIAL, THE RIGHT FILE NUMBER WILL BE WRITTEN IF
C       MFILE IS SET AS ONE LESS THAN THE FILE NUMBER WITH WHICH ONE
C       STARTS ON &INPUT1.
C       NFILE MUST BE THE FILE NUMBER ON WHICH YOU WANT TO STOP.
C
      DIMENSION U(9000),V(9000),FMT(10),PU(200),PV(200),CU(900),
     1CV(900),HT(9000),JH(9000)
      REAL*8 TITLE1(12),LABEL1/'F       '/,LABEL2/'        '/
      LOGICAL COMP,PLT,RPT
      NAMELIST/INPUT/COMP,N,NP,NX,DELT,RPT,PLT,NSTRT,NFILE/INPUT1/MFILE
C
      RAD=3.141592/180.
      NFILE=1
      RPT=.FALSE.
      PLT=.FALSE.
      NSTRT=0
      MFILE=0
C      READ FORMAT AND INPUT PARAMETERS
      READ(5,INPUT1)
    4 IEND=0
      READ(5,INPUT)
      WRITE(6,INPUT)
C      READ PLOT TITLE, 96 CHARACTERS INCL. USERS NAME
      READ(5,6) TITLE1
    6 FORMAT(10A8/2A8)
      WRITE(6,10)
   10 FORMAT(1H0)
C
      IREPT=0
C
C      READ AND DISCARD NSTRT POINTS
```

```
      IF(NSTRT.EQ.0)  GO TO 130
      DO 11 J=1,NSTRT
   11 READ(2,12) JUNK
   12 FORMAT(A4)
C
C      READ DATA
      NJ=0
  130 DO 13 J=1,N
      READ(2,875,END=200,ERR=350) U(J),V(J)
  875 FORMAT(2F12.5)
   13 NJ=J
C
C      IF COMP IS FALSE, FIND THE EAST AND NORTH COMPONENTS AND PUT
C      THEM IN U AND V.
   14 IF(COMP) GO TO 16
      DO 15 J=1,N
      UX=U(J)
      VX=V(J)*RAD
      U(J)=UX*SIN(VX)
   15 V(J)=UX*COS(VX)
C
C      PARAMETERS FOR COMPRESSING DATA
   16 NPTS=NP*NX
      NXI=N/NPTS
      JEVNPT=NPTS*NXI
      JEVN=N-JEVNPT
      KEVN=JEVN/NP
      LEVN=JEVN-KEVN*NP
C      WRITE MESSAGE
      WRITE(6,161) NP,NPTS,LEVN,JEVN
  161 FORMAT(/5X,'PLOTTING IS DONE EVERY ',I3,' POINTS, A CROSS IS PLOTT
     1ED EVERY ',I3,' POINTS, THERE ARE ',I3/5X,' POINTS NOT PLOTTED AND
     2 ',I3,' POINTS AFTER THE LAST CROSS.'/)
C
C      SUM THE COMPONENT DISPLACEMENTS IN KILOMETERS AND STORE NP POINTS
C      IN CU AND CV
   17 SUMU=0.
      SUMV=0.
      L=0
      K=1
      CU(1)=0.
      CV(1)=0.
      XDELT=DELT*3600.*1.E-5
      DO 27 M=1,NXI
   20 DO 26 LL=1,NX
      L=L+1
      DO 25 KK=1,NP
      K=K+1
```

```
      SUMU=SUMU+U(K)*XDELT
   25 SUMV=SUMV+V(K)*XDELT
      CU(L)=SUMU
   26 CV(L)=SUMV
      PU(M)=SUMU
   27 PV(M)=SUMV
C       FINISH THE LOOSE END
      IF(JEVN.EQ.0) GO TO 28
      DO 292 JJ=1,NX
      L=L+1
      DO 29 KK=1,NP
      IF(K.GE.N) GO TO 294
      K=K+1
      SUMU=SUMU+U(K)*XDELT
   29 SUMV=SUMV+V(K)*XDELT
      CU(L)=SUMU
  292 CV(L)=SUMV
  294 CU(L)=SUMU
      CV(L)=SUMV
C       SAVE THE NUMBER OF PLOTTED POINTS
      NT=L
C       FILL THE NEXT 3 WITH THE LAST VALUE TO FILL THE END OF THE
C       3-COLUMN PRINTOUT IN ALL CASES
   28 DO 31 J=1,3
      L=L+1
      CU(L)=CU(NT)
   31 CV(L)=CV(NT)
C
C       FORMAT FOR THREE COLUMNS
      NPRT=NT/3
      IEVN=NT-3*NPRT
      IF(IEVN.NE.0) NPRT=NPRT+1
C
C       PRINT HEADINGS
      WRITE(6,53)
   53 FORMAT(//T6,'HOURS',T15,'X(KM)',T24,'Y(KM)',T33,'HOURS',T42,
     1'X(KM)',T51,'Y(KM)',T61,'HOURS',T70,'X(KM)',T79,'Y(KM)'/)
C
C       COMPUTE TIME PARAMETERS
      TOTIM=FLOAT(N)*DELT
      DELTIM=FLOAT(NP)*DELT
      TIM1=DELTIM
      TIM2=FLOAT(NPRT)*DELTIM+DELTIM
      TIM3=2.*TIM2-DELTIM
      DO 50 J=1,NPRT
      K2=NPRT+J
      K3=K2+NPRT
      WRITE(6,55) TIM1,CU(J),CV(J),TIM2,CU(K2),CV(K2),TIM3,CU(K3),CV(K3)
```

```
   55 FORMAT(3(3X,F7.2,2X,F7.2,2X,F7.2))
C        INCREMENT TIME
      TIM1=TIM1+DELTIM
      TIM2=TIM2+DELTIM
      TIM3=TIM3+DELTIM
   50 IF(TIM3.GE.TOTIM) TIM3=TOTIM
C
C        COMPUTE VECTOR MEAN CURRENT,ETC.
      PI=3.141592
      PI2=2.*PI
      DIST=SQRT(SUMU*SUMU+SUMV*SUMV)
      ANG=ARSIN(SUMU/DIST)
C        PUT THE ANGLE IN THE RIGHT QUADRANT
      IF(ANG.GT.0.) GO TO 60
      IF(SUMV.GT.0.) GO TO 56
      ANG=ABS(ANG)+PI
      GO TO 62
   56 ANG=ANG+PI2
      GO TO 62
   60 IF(SUMV.LT.0.) ANG=PI-ANG
C        CONVERT ANGLE TO DEGREES
   62 ANG=ANG/RAD
C        COMPUTE MEAN VECTOR SPEED IN CM/SEC
      VMN=DIST*1.E5/(3600.*TOTIM)
      WRITE(6,65) DIST,ANG,TOTIM,VMN
   65 FORMAT(//5X,'DIST= ',F6.1,' KM, DIR= ',F5.1,' DEG., ELAPSED TIME=
     1',F6.1,' HRS, VECTOR MEAN SPEED= ',F6.2,'CM/SEC'//)
C        DIAGNOSTIC
      WRITE(6,68)
   68 FORMAT(3X,'NP    NX    NXI JEVNPT  KEVN'/3X,'K     L     M    NT    NPRT
     1   IEVN')
      WRITE(6,70) NP,NX,NXI,JEVNPT,KEVN,K,L,M,NT,NPRT,IEVN
   70 FORMAT(2X,I4,1X,I4,1X,I4,2X,I4,2X,I4/1X,I4,1X,I4,1X,I4,1X,I4,
     12X,I4,2X,I4/)
C
C        PLOT ROUTINE
      IF(.NOT.PLT) GO TO 80
      CALL DRAW(NT,CU,CV,1,0,LABEL1,TITLE1,0.,0.,0,0,0,0,6,09,0,LAST)
      WRITE(6,76) LAST
   76 FORMAT(5X,'LAST= ',I2)
C        PUT IN THE CROSSES
      CALL DRAW(NXI,PU,PV,3,2,LABEL2,TITLE1,0.,0.,0,0,0,0,6,09,0,LAST)
      WRITE(6,76) LAST
C
   80 IF(IREPT.GE.1) GO TO 999
      IF(.NOT.AFT) GO TO 999
C        SUBTRACT THE MEAN COMPONENTS FROM THE ARRAYS AND REPEAT
      IREPT=1
```

```
      UMN=SUMU*1.E5/(TOTIM*3600.)
      VMN=SUMV*1.E5/(TOTIM*3600.)
      DO 85 J=1,N
      U(J)=U(J)-UMN
   85 V(J)=V(J)-VMN
      WRITE(6,86) UMN,VMN
   86 FORMAT(/5X,'SUBTRACT MEAN U AND MEAN V, ',F6.2,2X,F6.2,' AND REPEA
     1T'//)
      GO TO 17
C
C      WE CHANGE N AND PROCESS AS USUAL
  200 N=NJ
      MFILE=MFILE+1
      WRITE(6,205) MFILE,NJ
  205 FORMAT(5X,'DETECTED EOF ',I2,' BEFORE REACHING N; RESET TO ',
     1I5,' AND PROCESS'/)
C      SET IEND=1 TO PREVENT THE READ AND DISCARD OPERATION
      IEND=1
      GO TO 14
C
  300 MFILE=MFILE+1
      WRITE(6,305) MFILE,NJ
  305 FORMAT(5X,'END OF FILE ',I2,' AFTER RECORD NO. ',I5/)
      IF(MFILE.GE.NFILE) GO TO 1000
      GO TO 4
  350 WRITE(6,355) NJ
  355 FORMAT(5X,'READ ERROR AFTER RECORD ',I5)
      GO TO 1000
C
C      READ AND DISCARD TO END OF FILE
  999 IF(NFILE.EQ.1) GO TO 1000
      IF(MFILE.GE.NFILE) GO TO 1000
      IF(IEND.EQ.1) GO TO 4
      DO 900 J=1,10000
      NJ=NJ+1
  900 READ(2,FMT,END=300,ERR=350) XJUNK
 1000 STOP
      END
C      THIS VERSION OF DRAW SCALES BOTH AXES THE SAME ON AUTOSCALE.
C      SEE CHANGES BEGINNING LABEL 2054.   R.G.PAQUETTE,FEB. 1974.
      SUBROUTINE DRAW(NUMPTS, X,Y, MODCUR, ITYPE, LABEL,
     1                 ITITLE, EXSCAL, YSCALE, IXLF, IYRIGH,
     2                  MODXAX, MODYAX, IWICE, IHIGH, IGRID,
     3                 LAST)
      DIMENSION X(900), Y(900), ITITLE(24), JXTIT(12), JYTIT(12),
     1 LTITLE(14),ICURV(1840),JGRID(100), ICONT(1)
      DATA ITEST/0/
           INTEGER IDATA(2)/1HX,1HY/ ,LABEL(2)
```

```
      REAL*8 ICODE,BLANK/8H        /,JXTIT,JYTIT,ISH,ISV
      REAL*8 ITIT,ICAT8(18)/5HIWIDE,5HIHIGH,8HMODEXAX.,5HIXUP.,
     1 8HMODEYAX.,8HIYRIGHT.,8HX-SCALE=,8H UNITS I,8HNCH.    ,8HY-SCALE=
     2,8H UNITS I,8HO ALL X ,8H   ADD -,8H   ADD +,8HVALUES. ,8HO ALL Y
     3,8H      14,8H      11/
C        CHECK PREVIOUS OPERATION OF ROUTINE, IF ANY. CODES ARE
C              ITEST = 0    IF PREVIOUS GRAPH, IF ANY, COMPLETED
C              ITEST = 1    IF PREVIOUS GRAPH NOT COMPLETED
C              ITEST = 2    IF ERROR FOUND WHILE MODCURV WAS ONE, OR IF
C                           MODCURV WAS ILLEGAL.
      IPOINT = ITYPE
      IF(ITEST - 2)1000,1001,1009
 1001 IF(MODCUR)1003,1002,1003
 1002 ITEST = 0
      GO TO 1000
 1003 IF(MODCUR - 1)1004,1002,1004
 1004 LAST = 3
      RETURN
C        SET UP ERROR RETURN ROUTINE. ENTRY AT STATEMENT 1005.
 1005 IF(ITEST)1009,1006,1009
 1006 IF(MODCUR)1007,1008,1007
 1007 PRINT 1100
 1100 FORMAT ( 59H NO FURTHER GRAPH OUTPUT UNTIL MODCURV NEXT IS ZERO OR
     1 ONE. ,/)
      ITEST = 2
      LAST = 2
      RETURN
 1008 PRINT 1101
 1101 FORMAT ( 30H THIS PLOT WILL NOT BE OUTPUT. ,/)
      LAST = 1
      RETURN
 1009 IF(MODCUR - 2)1010,1008,1010
 1010 IF(MODCUR - 3)1007,1011,1007
 1011 ITEST = 0
      GO TO 1008
C        CHECK LEGALITY OF INPUT ARGUMENTS.
 1000 IF(NUMPTS - 2)1,2,2
    1 PRINT 100
  100 FORMAT (/, 32H NUMPTS MUST NOT BE LESS THAN 2. )
      GO TO 1005
    2 IF(IPOINT)9000,9004,9001
 9000 PRINT 9100
 9100 FORMAT (/, 15H ILLEGAL ITYPE. )
      GO TO 1005
 9001 IF(IPOINT - 5)9002,9002,9000
 9002 IF(NUMPTS - 30)3,3,9003
 9003 PRINT 9101
 9101 FORMAT (/, 46H NUMPTS MUST NOT EXCEED 30 FOR POINT PLOTTING. )
```

```
      GO TO 1005
 9004 IF(NUMPTS - 900)3,3,9005
 9005 PRINT 9102
 9102 FORMAT (/, 28H NUMPTS MUST NOT EXCEED 900. )
      GO TO 1005
    3 IX=IDATA(1)
      IY=IDATA(2)
      AMAXX=X(1)
      AMAXY=Y(1)
      AMINX=X(1)
      AMINY=Y(1)
      DO 1020 I=2,NUMPTS
      AMAXX=AMAX1(X(I),AMAXX)
      AMAXY=AMAX1(Y(I),AMAXY)
      AMINX=AMIN1(X(I),AMINX)
 1020 AMINY=AMIN1(Y(I),AMINY)
 1022 IF (AMAXX-AMINX) 1025,1023,1025
 1023 IF (AMAXY-AMINY) 1025,1024,1025
 1024 PRINT 1103
 1103 FORMAT (/, 33H ALL POINTS HAVE THE SAME COORDINATES. )
      GO TO 1005
 1025 IF(ITEST)4,7,4
    4 IF(MODCUR-2)5,2240,5
    5 IF(MODCUR-3)6,2240,6
    6 PRINT 101
  101 FORMAT (/, 17H ILLEGAL MODCURV. )
      GO TO 1005
    7 IF(MODCUR)6,9,8
    8 IF(MODCUR - 1)6,9,6
    9 IF(IWIDE)10,11,12
   10 ITIT=IDAT8(1)
      PRINT 102, ITIT, ITIT
  102 FORMAT (/,  9H ILLEGAL ,A5,29H. GRAPH WILL BE PLOTTED WITH ,A5,
     1             5H = 8. ,/)
   11 JWIDE = 8
      GO TO 14
   12 IF(IWIDE - 9)13,13,10
   13 JWIDE = IWIDE
   14 IF(IHIGH)15,16,17
   15 ITIT=IDAT8(2)
      PRINT 102, ITIT, ITIT
   16 JHIGH = 8
      GO TO  19
 2240 CONTINUE
C     BACKSPACE 49
      GO TO 240
   17 IF(IHIGH - 15)18,18,15
   18 JHIGH = IHIGH
```

```
   19 NODXAX = MODXAX
      IF(MODXAX)20,27,21
   20 ITIT=IDAT8(3)
      PRINT 104, ITIT, IX
  104 FORMAT (/,  9H ILLEGAL ,A8, 32H GRAPH WILL BE PLOTTED WITH MODE,
     1          A1,  7HAX = 0. ,/)
      NODXAX = 0
      GO TO 27
   21 IF(MODXAX - 2)27,22,20
   22 IF(IXUP - JHIGH)24,24,23
   23 ITIT=IDAT8(4)
      PRINT 104, ITIT, IX
      NODXAX = 0
      GO TO 27
   24 IF(IXUP)23,26,26
   26 JXUP = IXUP
   27 NODYAX = MODYAX
      IF(MODYAX)28,35,29
   28 ITIT=IDAT8(5)
      PRINT 104, ITIT, IY
      NODYAX = 0
      GO TO 35
   29 IF(MODYAX - 2)35,30,28
   30 IF(IYRIGH - JWIDE)32,32,31
   31 ITIT=IDAT8(6)
      PRINT 104, ITIT, IY
      NODYAX = 0
      GO TO 35
   32 IF(IYRIGH)31,34,34
   34 JYRIGH = IYRIGH
C           INITIALIZE PRIOR TO SCALING AND AXIS LOCATING.
C           IFLAG = 0 FOR PASS WITH XDATA. IFLAG = 1 FOR PASS WITH YDATA.
   35 IFLAG = 0
      BETA = 0.
      SCALE = EXSCAL
      IAXIS = JYRIGH
      MODE = NODYAX
      ISIZE = JWIDE
      IXY = IX
      IYX = IY
      AMAX = AMAXX
      AMIN = AMINX
      GO TO 52
   50 IFLAG = 1
      BETA = 0.
      SCALE=YSCALE
      IAXIS = JXUP
      MODE = NODXAX
```

```
      ISIZE = JHIGH
      AMAX = AMAXY
      AMIN = AMINY
      IXY = IY
      IYX  = IX
C           CHECK SCALE AND GO TO FIXED OR AUTO SCALE ROUTINES.
   52 IF(SCALE)53,59,58
   53 PRINT 114, IXY, IXY
  114 FORMAT (/,  9H ILLEGAL ,A1,39HSCALE. GRAPH WILL BE PLOTTED WITH AU
     1TO ,A1, 7H-SCALE. ,/)
      GO TO 59
C     EXPRESS FIXED SCALE IN E FORMAT WITH ONE FIGURE SIGNIFICANCE.
   58 CALL SCALIT(SCALE,ISCL10,FACTOR,1)
      SCALE = FACTOR*10.**ISCL10
C           CHECK AND COMPUTE AXIS LOCATION IF NECESSARY. FIXED SCALE
C           CASE. ITAG = 0 IF ORIGIN ON GRAPH OR 1 IF IT IS SUPPRESSED.
      IF(MODE - 1)1032,1031,1030
 1030 ITAG =0
      GO TO 203
 1031 PRINT 1104 , IYX, IXY, IXY
 1104 FORMAT (/, 5H MODE,A1,24HAX MUST NOT BE 1 UNLESS ,A1,57HSCALE IS C
     1 (AUTO-SCALE). GRAPH WILL BE PLOTTED WITH AUTO ,A1, 7H-SCALE. ,/)
      GO TO 59
 1032 IF (AMAX-AMIN) 1038,1039,1038
 1039 IF(AMAX)1036,1034,1037
 1034 IAXIS = ISIZE/2
      GO TO 1030
 1036 IAXIS = ISIZE
      GO TO 1030
 1037 IAXIS = 0
      GO TO 1030
 1038 IF (SIGN(1.,AMAX)-SIGN(1.,AMIN)) 1040,1039,1040
 1040 ASIZE = ISIZE
      IAXIS = -AMIN/(AMAX - AMIN)*ASIZE +0.5
      GO TO 1030
C           AUTO SCALE ROUTINE.
   59 IF(MODE - 1)60,64,69
   60 AMAX=AMAX1(0.,AMAX)
      AMIN=AMIN1(0.,AMIN)
   64 IF (AMAX-AMIN) 68,65,68
   65 PRINT 116, IXY, IXY, IYX
  116 FORMAT (/,  5H ALL ,A1,47H VALUES EQUAL. AUTO SCALE POSSIBLE ONLY
     1IF THE ,A1,29H VALUES ARE NON-ZERO AND MODE,A1, 7HAX = 2. )
      GO TO 1005
   68 ASIZE = ISIZE
      SCALE = (AMAX - AMIN)/ASIZE
      GO TO 33
   69 IF(AMAX-AMIN)74,70,74
```

```
   70 IF (AMAX) 74,71,74
   71 PRINT 118, IXY
  118 FORMAT (/,  5H ALL ,A1,38H VALUES ZERO. AUTO SCALE NOT POSSIBLE. )
      GO TO 1005
   74 IF (AMAX) 76,76,75
   75 IF(ISIZE - IAXIS)77,76,77
   76 SCALE1 = 0.
      GO TO 78
   77 AXIS = IAXIS
      ASIZE = ISIZE
      SCALE1 = AMAX/(ASIZE - AXIS)
   78 IF (AMIN) 79,79,80
   79 IF(IAXIS)81,80,81
   80 SCALE2 = 0.
      GO TO 82
   81 AXIS = IAXIS
      SCALE2 = -AMIN/AXIS
   82 IF(SCALE1 + SCALE2)1984,1982,1984
 1982 PRINT 1983, IYX, IYX
 1983 FORMAT (/, 56H NONE OF THE PLOT LIES ON THE GRAPH WITH THIS SPECIF
     1IED ,A1,47H-AXIS LOCATION. GRAPH WILL BE PLOTTED WITH MODE,A1,
     2  7HAX = 0.   ,/)
      MODE = 0
      GO TO 60
 1984 SCALE=AMAX1(SCALE1,SCALE2)
   83 CALL SCALIT(SCALE,ISCL10,FACTOR,3)
      IF(FACTOR - 5.05)85,85,84
   84 FACTOR = 1
      ISCL10 = ISCL10+1
      GO TO 90
   85 IF(FACTOR - 2.02)87,87,86
   86 FACTOR = 5
      GO TO 90
   87 IF(FACTOR - 1.01)89,89,88
   88 FACTOR = 2
      GO TO 90
   89 FACTOR = 1
   90 SCALE = FACTOR*10.**ISCL10
C           COMPUTE AXIS LOCATION IF NECESSARY. AUTO SCALE CASE.
      IF(MODE - 1)92,91,93
   91 IF (SIGN(1.,AMAX)-SIGN(1.,AMIN)) 92,94,92
   92 IAXIS = -AMIN/SCALE + 0.5
   93 ITAG = 0
      GO TO 203
   94 IF(AMAX)95,95,200
   95 IAXIS = ISIZE
      BETA = -AMAX/SCALE
      IF(BETA - 1.E+12)99,99,96
```

```
   96 PRINT 120, IXY
  120 FORMAT (/, 15H THE ORIGIN OF ,A1, 43H CANNOT BE OFFSET MORE THAN 1
     1.0E+12 INCHES. )
      GO TO 1005
   99 IBETA = BETA + 0.5
      BETA = -IBETA
C           BETA IS THE NUMBER OF INCHES OF ORIGIN SUPPRESSION,POSITIVE IF
C           TRUE ORIGIN IS BELOW OR TO LEFT OF THE GRAPH.
      IF(BETA + 1.)97,97,99
   97 ITAG = 1
      GO TO 203
  200 IAXIS = 0
      BETA = AMIN/SCALE
      IF(BETA - 1.E+12)201,201,96
  201 IBETA = BETA + 0.5
      BETA = IBETA
      IF(BETA - 1.)99,202,202
  202 ITAG = 1
C           RELEASE RESULTS TO REMAINING PART OF PROGRAM. START SECOND
C           PASS FOR Y VALUES IF NOT YET COMPUTED.
  203 IF(IFLAG)205,204,205
  204 SCALEX = SCALE
      IXFACT  = FACTOR
      IXSC10 = ISCL10
      IXAXIS = IAXIS
      ITAGX  = ITAG
      ISIZEX = ISIZE
      BETAX = BETA
      GO TO 50
  205 BETAY = BETA
      SCALEY = SCALE
      IYFACT =  FACTOR
      IYSC10 = ISCL10
      IYAXIS = IAXIS
      ITAGY  = ITAG
      ISIZEY = ISIZE
C      MAKE THE SCALING THE SAME ON THE TWO AXES .
 2054 IF(SCALEX.GT.SCALEY) GOTO 2055
      SCALEX=SCALEY
      IXFACT=IYFACT
      IXSC10=IYSC10
      BETAX=BETAX*SCALEX/SCALEY
      GO TO 206
 2055 SCALEY=SCALEX
      IYFACT=IXFACT
      IYSC10=IXSC10
      BETAY=BETAY*SCALEY/SCALEX
C      END OF CHANGES
```

```
C           THIS COMPLETES CALCULATION OF SCALE FACTORS ETC. NOW GENERATE
C           TAPE RECORDS. FIRST, THE SCALE FACTOR TITLES.
  206 JXTIT(1)=ICAT8(7)
      JXTIT(2)=ICODE(SCALEX)
      JXTIT(3)=ICAT8(8)
      JXTIT(4)=IDAT8(9)
      JYTIT(1)=ICAT8(10)
      JYTIT(2)=ICODE(SCALEY)
      JYTIT(3)=ICAT8(8)
      JYTIT(4)=ICAT8(9)
      DO 9206 I=5,11
      JXTIT(I)=BLANK
 9206 JYTIT(I)=BLANK
      IF(ITAGX)211,211,207
  207 IF(BETAX)208,208,209
  208 JXTIT(5)=ICAT8(13)
      GO TO 210
  209 JXTIT(5)=ICAT8(14)
  210 JXTIT(6)=ICODE(BETAX*SCALEX)
      JXTIT(7)=ICAT8(11)
      JXTIT(8)=ICAT8(12)
      JXTIT(9)=IDAT8(15)
  211 IF(ITAGY)216,216,212
  212 IF(BETAY)213,213,214
  213 JYTIT(5)=ICAT8(13)
      GO TO 215
  214 JYTIT(5)=ICAT8(14)
  215 JYTIT(6)=ICODE(BETAY*SCALEY)
      JYTIT(7)=ICAT8(11)
      JYTIT(8)=ICAT8(16)
      JYTIT(9)=ICAT8(15)
  216 CONTINUE
C           INSERT TITLE SIZE (C23) AHEAD OF MAIN TITLE RECORD.
C          TEST FOR ALL BLANK TITLES.
C           NOW GENERATE AXES RECORDS.
 9091 LFTMGN = 0*100
      IBTMGN = 1*100
      IH = LFTMGN
      JH = IBTMGN +IYAXIS*100
      LH = ISIZEX*100
      IHL = LFTMGN + ISIZEX*100 - 107
      JHL = JH - 13
      IHL2 = -100
      IVH  = (ISIZEX -IXAXIS - 1)*IXFACT
      IVH2 = -IXFACT
      NH = ISIZEX
      ISH= IDAT8(17)
      IV = LFTMGN + IXAXIS*100
```

```
      JV = IBTMGN
      LV = ISIZEY*100
      IVL = IV - 3
      JVL = IBTMGN + ISIZEY*100 - 107
      JVL2 = -100
      IVV = (ISIZEY - IYAXIS - 1)*IYFACT
      IVV2 = -IYFACT
      INV = ISIZEY
      ISV=ICAT8(18)
C         NOW GENERATE CURVES.
      SCX = 100./SCALEX
      SCY = 100./SCALEY
      EXAXIS= IXAXIS*100
      YAXIS = IYAXIS*100
      ALFMGN = LFTMGN
      BOTMGN = IBTMGN
      SHIFTX =EXAXIS - BETAX*100. + ALFMGN
      SHIFTY = YAXIS - BETAY*100. + BOTMGN
      EXSIZE= ISIZEX*100 + LFTMGN + 60
      SIZEX = LFTMGN - 60
      YSIZE = ISIZEY*100 + IBTMGN + 70
      SIZEY = IBTMGN - 70
  240 IF(IPOINT)9010,9007,9010
 9007 IF(MOD(NUMPTS,2)) 9700,9701,9700
 9700 ISW TCH=1
      GO TO 242
 9701 ISW TCH=2
  242 INUM=((NUMPTS+1)/2)*4
      DO 244 I=1,INUM,4
      C1=X((I+1)/2)*SCX+SHIFTX
      C2=Y((I+1)/2)*SCY+SHIFTY
      IF (I+3-INUM) 241,9241,241
 9241 GO TO (9242,241),ISW TCH
 9242 C3=C1
      C4=C2
      GO TO 9243
  241 C3=X((I+1)/2+1)*SCX+SHIFTX
      C4=Y((I+1)/2+1)*SCY+SHIFTY
 9243 C1=AMIN1(C1,EXSIZE)
      IC1=AMAX1(C1,SIZEX)
      C2=AMIN1(C2,YSIZE)
      IC2=AMAX1(C2,SIZEY)
      C3=AMIN1(C3,EXSIZE)
      IC3=AMAX1(C3,SIZEX)
      C4=AMIN1(C4,YSIZE)
      IC4=AMAX1(C4,SIZEY)
      ICURV(I)=IC1
      ICURV(I+1)=IC2
```

```
      ICURV(I+2)=IC3
  244 ICURV(I+3)=IC4
  246 CONTINUE
C          NOW WRITE RECORDS.
 9010 IF(MODCUR-1)260,260,9015
  260 CALL PLCTS (0,0,0)
      XAXIS=0.
      YAXIS=0.
      CALL SYMBOL(XAXIS,YAXIS,.14,JXTIT,0.,72)
      YAXIS=YAXIS-.24
  261 CALL SYMBOL(XAXIS,YAXIS,.14,JYTIT,0.,72)
      YAXIS=YAXIS-.31
 9268 CALL SYMBOL(XAXIS,YAXIS,.21,ITITLE,0.,48)
      YAXIS=YAXIS-.31
 9270 CALL SYMBOL(XAXIS,YAXIS,.21,ITITLE(13),0.,48)
 9271 XAXIS=FLOAT(IH)/100.
      YAXIS=FLOAT(JH)/100.
      CALL PLOT(XAXIS,YAXIS,3)
      XAXIS=FLOAT(IH+LH)/100.
      CALL PLOT(XAXIS,YAXIS,2)
      CALL SPECNO(IVH,IVH2,NH,XAXIS,YAXIS,1)
      XAXIS=FLOAT(IV)/100.
      YAXIS=FLOAT(JV)/100.
      CALL PLOT(XAXIS,YAXIS,3)
      YAXIS=FLOAT(JV+LV)/100.
      CALL PLOT(XAXIS,YAXIS,2)
      CALL SPECNO(IVV,IVV2,INV,XAXIS,YAXIS,2)
 9015 IF(IFCINT)9020,270,9020
  270 CALL SUB1(ICURV,INUM)
      CALL WHERE(XAXIS,YAXIS)
      CALL SYMBOL(XAXIS,YAXIS,.07,LABEL,0.,4)
 9020 IF (MODCUR-1) 272,272,9025
  272 IF(IGRID - 1)9025,273,9025
C          GENERATE GRID IF CALLED FOR.
  273 IX100 = ISIZEX*100
      IY100 = ISIZEY*100
      NEXT1 = IBTMGN
      NEXT2 = LFTMGN + IX100
      DO 1274 J=1,80,8
      JGRID(J)=LFTMGN
      JGRID(J+1)=NEXT1
      JGRID(J+2)=NEXT2
      JGRID(J+3)=NEXT1
      IF(NEXT1 - IBTMGN - IY100)1273,1275,1275
 1273 NEXT1 = NEXT1 + 100
      JGRID(J+4)=NEXT2
      JGRID(J+5)=NEXT1
      JGRID(J+6)=LFTMGN
```

```
      JGRID(J+7)=NEXT1
      IF(NEXT1 - IBTMGN - IY10C)1274,1276,1276
 1274 NEXT1 = NEXT1 + 100
 1275 JGRID(J+4)=NEXT2
      JGRID(J+5)=NEXT1
      JGRID(J+6)=NEXT2
      JGRID(J+7)=NEXT1
 1276 CONTINUE
      NUMGRD=J+7
      CALL SUB1(JGRID,NUMGRD)
 1277 NEXT1 = LFTMGN
      NEXT2 = IBTMGN + IY10C
      DO 1279 J=1,48,8
      JGRID(J)=NEXT1
      JGRID(J+1)=IBTMGN
      JGRID(J+2)=NEXT1
      JGRID(J+3)=NEXT2
      IF(NEXT1 - LFTMGN - IX10C)1278,1280,1280
 1278 NEXT1 = NEXT1 + 100
      JGRID(J+4)=NEXT1
      JGRID(J+5)=NEXT2
      JGRID(J+6)=NEXT1
      JGRID(J+7)=IBTMGN
      IF(NEXT1 - LFTMGN - IX10C)1279,1281,1281
 1279 NEXT1 = NEXT1 + 100
 1280 JGRID(J+4)=NEXT1
      JGRID(J+5)=NEXT2
      JGRID(J+6)=NEXT1
      JGRID(J+7)=NEXT2
 1281 CONTINUE
      NUMGRD=J+7
      CALL SUB1(JGRID,NUMGRD)
 9025 IF(IPOINT)9030,276,9030
C           GENERATE POINT PLOT RECORDS IF CALLED FOR.
 9030 IOUT = 0
      DO 9050 I=1,NUMPTS
      C1 = X(I)*SCX + SHIFTX
      C2 = Y(I)*SCY + SHIFTY
      IF(C1 - EXSIZE)9031,9031,9034
 9031 IF(C2 - YSIZE)9032,9032,9034
 9032 IF(C1 - SIZEX)9034,9033,9033
 9033 IF(C2 - SIZEY)9034,9035,9035
 9034 IOUT = IOUT +1
      GO TO 9050
 9035 IC1 = C1
      IC2 = C2
      GO TO (9036,9037,9038,9039,9040),IPOINT
C           GENERATE CROSS.
```

```
 9036 ICURV(1)=IC1-5
      ICURV(2)=IC2-5
      ICURV(3)=IC1+5
      ICURV(4)=IC2+5
      ICURV(5)=IC1
      ICURV(6)=IC2
      ICURV(7)=IC1-5
      ICURV(8)=IC2+5
      ICURV(9)=IC1+5
      ICURV(10)=IC2-5
      ICURV(11)=IC1+5
      ICURV(12)=IC2-5
      INUM=12
      GO TO 9041
C        GENERATE PLUS.
 9037 ICURV(1)=IC1
      ICURV(2)=IC2-5
      ICURV(3)=IC1
      ICURV(4)=IC2+5
      ICURV(5)=IC1
      ICURV(6)=IC2
      ICURV(7)=IC1-5
      ICURV(8)=IC2
      ICURV(9)=IC1+5
      ICURV(10)=IC2
      ICURV(11)=IC1+5
      ICURV(12)=IC2
      INUM=12
      GO TO 9041
C        GENERATE SQUARE.
 9038 ICURV(1)=IC1+4
      ICURV(2)=IC2-4
      ICURV(3)=IC1+4
      ICURV(4)=IC2+4
      ICURV(5)=IC1-4
      ICURV(6)=IC2+4
      ICURV(7)=IC1-4
      ICURV(8)=IC2-4
      ICURV(9)=IC1+4
      ICURV(10)=IC2-4
      ICURV(11)=IC1+4
      ICURV(12)=IC2-4
      INUM=12
      GO TO 9041
C        GENERATE DIAMOND.
 9039 ICURV(1)=IC1+5
      ICURV(2)=IC2
      ICURV(3)=IC1
```

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      ICURV(4)=IC2+5
      ICURV(5)=IC1-5
      ICURV(6)=IC2
      ICURV(7)=IC1
      ICURV(8)=IC2-5
      ICURV(9)=IC1+5
      ICURV(10)=IC2
      ICURV(11)=IC1+5
      ICURV(12)=IC2
      INUM=12
      GO TO 9041
C          GENERATE TRIANGLE.
 9040 ICURV(1)=IC1+5
      ICURV(2)=IC2-3
      ICURV(3)=IC1
      ICURV(4)=IC2+6
      ICURV(5)=IC1-5
      ICURV(6)=IC2-3
      ICURV(7)=IC1+5
      ICURV(8)=IC2-3
      INUM=8
 9041 CALL SUB1(ICURV,INUM)
      IF(I-NUMPTS)9043,9042,9043
 9042 CALL WHERE(XAXIS,YAXIS)
      CALL SYMBOL(XAXIS,YAXIS,.07,LABEL(2),0.,4)
      GO TO 9046
 9043 IF(I - 1)9045,9044,9045
 9044 CALL WHERE(XAXIS,YAXIS)
      CALL SYMBOL(XAXIS,YAXIS,.07,LABEL(1),0.,4)
      GO TO 9046
 9045 CONTINUE
 9046 CONTINUE
      CALL SUB1(ICURV,INUM)
 9050 CONTINUE
      IF(IOUT)9048,276,9048
 9048 PRINT 9104, IOUT
 9104 FORMAT (/, 1X, I2, 29H POINT(S) WERE OFF THE GRAPH. ,/)
C          SET UP RETURN.
  276 IF(MCOCUR)277,278,277
  277 IF(MCOCUR - 3)279,278,279
  278 ITEST = 0
      YAXIS=JHIGH+4
      CALL PLOT(0.0,YAXIS,-3)
      CALL PLOT (0.,0.,999)
      WRITE(6,130) ITITLE
  130 FORMAT (/13H GRAPH TITLE0/2(5X,12A4/),18H HAS BEEN PLOTTED.)
      IDUMMY = ITYP2(IDUMMY)
      GO TO 280
```

```
  279 ITEST = 1
  280 LAST=0
      RETURN
C          THESE ARE THE NORMAL RETURNS.
      END
      SUBROUTINE SCALIT (ANUMBR,ISCL10,FACTOR,MODE)
C          FINDS FACTOR (BETWEEN 1.0 AND 9.99...) AND SCALE OF 10 AS
C          DEFINED BY     ANUMBER = FACTOR*10.**ISCAL10.
C          MODE IS THE NUMBER OF SIGNIFICANT FIGURES REQUIRED. THIS MUST
C          BE BETWEEN 1 AND 10 OR IT WILL BE PUT EQUAL TO SIX.
      ISCL10=ALOG(ANUMBR)*.43429448
      FACTOR = ANUMBR/10.**ISCL10
      IF(FACTOR - 0.1)1,2,2
    1 FACTOR = FACTOR*100.
      ISCL10 = ISCL10 - 2
      GO TO 8
    2 IF(FACTOR - 1.0)3,8,4
    3 FACTOR = FACTOR*10.
      ISCL10 = ISCL10 - 1
      GO TO 8
    4 IF(FACTOR - 100.0)6,5,5
    5 FACTOR = FACTOR/100.
      ISCL10 = ISCL10 + 2
      GO TO 8
    6 IF(FACTOR - 10.0)8,7,7
    7 FACTOR = FACTOR/10.
      ISCL10 = ISCL10 + 1
    8 IF(MODE)9,9,10
    9 MODE = 6
      GO TO 11
   10 IF(MODE - 10)11,11,9
   11 IFACTR = FACTOR*10.**(MODE - 1) + 0.5
      FACTOR = IFACTR
      FACTOR = FACTOR/10.**(MODE - 1)
      IF(FACTOR - 10.)13,12,12
   12 FACTOR = 1.
      ISCL10 = ISCL10 + 1
   13 RETURN
      END
      FUNCTION ICODE (ANUMER)
C          CODES ABSOLUTE VALUE OF A FLOATING POINT NUMBER (BETWEEN
C          1.0E-100 AND 1.0E+100) INTO 8-CHARACTER BCD WORD OF THE FORM
C          1.23E+45. ICODE = 8H0.00E+00 IF MAGNITUDE OUT OF RANGE.
       REAL*8 ICODE
      DIMENSION II(8)
      DATA IPLUS/4H000+/,IMINUS/4H000-/,IE/4H000E/,IPER/4H000./
      IPLUS=-252645298
      BNUMER=ABS(ANUMBR)
```

```
    2 CALL  SCALIT(BNUMBR,ISCL10,FACTOR,3)
      ISGNSC=ISIGN(1,ISCL10)
      ISCL10=IABS(ISCL10)
     .IFACT = FACTOR*100.001
      II(8)=MOD (ISCL10,10)
      II(7)=ISCL10/10
      IF(ISGNSC) 4,3,3
    3 II(6)=IPLUS
      GO TO 5
    4 II(6)=IMINUS
    5 II(5)=IE
      II(4)=MOD(IFACT,10)
      II(3)=(MOD(IFACT,100))/10
      II(2)=IPER
      II(1) = IFACT/100
      CALL ENCODE(8,ICODE,II)
      RETURN
      END
      FUNCTION IIYP2 (IDUMMY)
C           TYPE WORD GRAPH.
      RETURN
      END
      SUBROUTINE SUB1(IA,N)
      DIMENSION IA(2)
      IPEN=3
      DO 100 I=1,N,2
      X=IA(I)
      X=X/100.
      Y=IA(I+1)
      Y=Y/100.
      CALL PLOT(X,Y,IPEN)
      IPEN=2
  100 CONTINUE
      RETURN
      END
      SUBROUTINE SPECNO(IVH,IVH2,NH,XAXIS,YAXIS,IA)
      DATA MINUS/4H000-/
      DIMENSION II(4)
      MINUS=-252645280
      GO TO (100,200),IA
  100 TH=0.
      GO TO 300
  200 TH=90.
  300 STH=SIN (TH*.0174533)
      CTH=COS (TH*.0174533)
      X=XAXIS-1.*CTH-.1*STH
      Y=YAXIS-.1*CTH-1.*STH
      INUMS=IVH
```

```
      DO 700 K=1,NH
      I=0
      INUM=INUMS
      IF(INUM) 400,500,500
  400 I=1
      II(1)= MINUS
      INUM=-INUM
  500 I=I+1
      II(I)=INUM/100
      INUM=INUM-II(I)*100
      I=I+1
      II(I)=INUM/10
       INUM=INUM-II(I)*10
      I=I+1
      II(I)=INUM
      CALL ENCODE(I,IS,II)
      CALL SYMBOL(X,Y,.07,IS,TH,I)
      INUMS=INUMS+IVH2
      X=X-1.*CTH
  700 Y=Y-1.*STH
      RETURN
      END
```

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